Elementary Logic
Induction

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ELEMENTARY LOGIC

INDUCTION

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PREFACE

This book is intended to serve as a companion to the Deductive part of the Elementary Logic. Here, too, my aim has been to present the main doctrines in a simple and intelligible form. The danger of substituting unintelligent memorising for real mental work is even greater in this part of the subject. Inductive Logic is the study of the Scientific Method, and a writer finds it appropriate and convenient to illustrate the processes and principles described from the sciences themselves. This plan, however, leads to a difficulty of which the magnitude can be appreciated only by those who have to teach the subject. Indian students who take up Inductive Logic as a part of their course know nothing or next to nothing of the physical sciences. The result is that some of the illustrations used in the text books, beautiful as they may be in themselves, are quite unintelligible to them. Failing to grasp the ideas, the students have to content themselves with words. I have attempted to illustrate the principles of scientific investigation by simple instances. Sometimes examples have been chosen

from every-day life, for, as I have said elsewhere in this volume, even out of the Laboratory, we are constantly seeking for causes of effects and effects of causes, and our procedure is not illogical. When the student studies the character of the scientific method, he must never lose sight of the fact that it is a method which he himself also uses pretty frequently, though in a rudimentary way.

DIWAN CHAND.

SYLLABUS IN LOGIC (INDUCTION)

1. THE PUNJAB UNIVERSITY.

I.—Definition, Scope and Use of Induction. Observation and Experiment. Regulative Principles of Observation and Experiment. Advantages of Experiment over Observation. Classification and Nomenclature. Generalisation.

II.—Perfect and Imperfect Induction. The assumptions of Scientific Induction. The Law of Causation. Uniformity of Nature. Causes and Conditions. Plurality of Causes. Intermixture of Effects. Discovery and Proof as the object of Induction.

III.—The Inductive Methods. Imperfect Inductions. Simple Enumeration. Analogy.

The Deductive Method of Investigation. The value and function of an Hypothesis. Conditions of Validity of an Hypothesis. Crucial Instances. Empirical Generalisations and Laws of Nature. Explanation and its various forms.

IV.—Fallacies of Induction.

2. THE BOARD OF HIGH SCHOOL AND INTERMEDIATE EDUCATION, U.P.

The nature and pre-suppositions of inductive inference. Causation, its significance and importance in induction. Observation and Experiment. Classification and Nomenclature. Hypothesis. Imperfect in-

ductions—simple enumeration and analogy. Application of inductive methods. Methods of scientific induction. Analysis of inductive arguments. Explanation and establishment of laws. The relation of induction to deduction Fallacies.

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CHAPTER I

DEFINITION, SCOPE AND USE OF INDUCTION

1. The Nature of Inference.

'The problem of Inference,' says Bosanquet, 'is something of a Paradox. Inference consists in asserting as fact or truth, on the ground of certain given facts or truths, something which is not included in those data. We have not got inference unless the conclusion (i) is necessary from the premisses, and (ii) goes beyond the premisses. To put the paradox quite roughly—we have not got inference unless the conclusion is (i) in the premisses, (ii) outside the premisses.'* The essential features of an Inference are the novelty of the conclusion and the necessity with which it follows from the given data. The conclusion is at once new and not new. It is new not in the sense of being unconnected with the data, but in the sense of being presented to consciousness

* Essentials of logic, 137.

in a form in which it was not present before. What was implicit before becomes now explicit. To draw out the implications of the premisses—to disimplicate them—is the business of Inference.

2. The Basis of Inference.

But what justification is there to pass from one truth to another? If these truths were unconnected, there would be no way of passing from one to the other. We can pass from one to the other, because we assume that they are related to one another as fragments of the same Truth. Corresponding to this Truth, there is the Reality which this Truth represents. If that Reality were an aggregate of unconnected parts, the Truth also would be such an aggregate. All inference is based on the assumption that Reality is one. This does not amount to denying the existence of diversity. Who can shut his eyes to the diversity that seems to be all-pervading in Nature? There is diversity in Nature, but the diverse elements are parts of a system. A system is a whole of inter-related parts. As a simple instance, we may take the human body. The lungs are different from the eye; the nervous system is different from the stom-

ach. But in spite of the diversity of parts, the human body is one thing : it has one life, and the various organs co-operate in the interest of that one life. If I knew enough about the structure and plan of the human body, I could mentally construct the whole body from a single part—an ear or a tooth. From the footprint of an animal we infer about its stomach, from its horns about the structure of its teeth. Now physical science assumes that the whole of physical Reality is one system of inter-related parts, and we can infer from one part of it something about another part just because it is such a system. The events that are happening are also related as parts of a system and so can be inferred from one another. We may start with the parts and construct the whole, or start with the knowledge of the whole and conclude about the parts. The basis of inference in both cases is the same—the Unity of Reality or Truth—but the difference of procedure gives rise to two forms of inference.

3. Induction and Deduction.

These two forms are known as Induction and Deduction. In Induction we start from the parts, in Deduction we start from the

whole. Some easy examples will make this plain. We say—

> All men are mortal,
> Socrates is a man,
> Therefore, Socrates is mortal.

Here we start with a law about mankind in general and proceed to apply it in the case of one particular individual. Suppose, however, that the major premiss of this syllogism is challenged. How do we know that all men are mortal? All that we can do is to examine some individual cases and from them to pass on to the general law. This would be Induction. Now that we know that quinine cures malaria, we have simply to assure ourselves that a particular case is one of malaria and then may administer quinine. But how did we come to know that quinine cures all cases of malaria? Obviously, by examining some particular cases. The major premiss of a syllogism in most cases (in the opinion of some, in all cases) is the result of previous Inductions. This leads Logicians of the Empirical School to the conclusion that really all inference is from particular cases. 'General propositions,' says Mill, 'are merely registers of such (i.e., inductive) inferences already made, and short formulæ for

making more. The major premiss of a syllogism consequently is a formula of this description; and the conclusion is not an inference drawn from the formula; the real logical antecedent or premiss being the particular facts from which the general proposition was collected by Induction.' This is an extreme position. On the other hand, there are those who maintain that all inference is Deductive. "In the strict formal sense," says Bosanquet, "there can be no inference from particulars to particulars......... If the terms are really particulars, 'X is A, Y is B, Z is C,' one is helpless; they do not point to anything further at all; there is no bridge from one to the other."* If from A, B and C we can infer about X and Y, it must be because what is true of A, B and C, is also true of X and Y. The Uniformity of Nature is the understood major premiss in all inference that is regarded as Inductive.

As we shall see in a future chapter, the two processes are neither reducible to one nor mutually antagonistic. They are complementary one of the other, and in the explanation of phenomena we employ both of them as occasion requires. They are both steps in what may be called the Scientific Method.

**Ibid*, 139.

The contrast between Deduction and Induction has been expressed in various ways. We have said above that in Induction we pass from particular facts to general truths, and in Deduction we pass from general truths to their application in particular cases. In every syllogism of the standard form, the major premiss must be a universal, and, as we shall see in detail below, the conclusion in every Induction must be a general proposition. This truth is sometimes expressed by saying that in Induction we *ascend* to a general *principle*, whereas in Deduction we *descend* to individual *facts*, which are the applications of a principle.

In Deduction, our business is to see how propositions are related and what some of them taken together involve. We are not concerned with the *truth* of the propositions. In Induction, we are concerned with their truth. If I say that all men are triangles and all triangles are rational, I am committed to the proposition—All men are rational. Deduction is not concerned with the truth of the premisses or of the conclusion. Its concern is to see whether from the premisses given the conclusion does necessarily follow. For this reason, Deductive Logic is known as the Logic of Consistency. Inductive Logic cannot be indifferent to truth. Its whole being is in the interest

of truth, and, therefore, it is called Logic of Truth, or Logic of Science. The same difference is expressed by saying that Deduction is concerned with the form and Induction with the matter of Thought.

A slightly different way of expressing the same distinction is to say that in Deduction we seek to establish a relation between ground and consequent, whereas in Induction we want to connect cause and effect. Mathematics employs Deductive reasoning, whereas in Physical Sciences, like Chemistry, Induction is mainly employed.

It is sometimes said that all Science is the outcome of Analysis and Synthesis. Analysis breaks a given whole into the parts of which it is composed. Synthesis puts together parts taken from various wholes to construct a new whole. It is thus that the edifice of Science, like an ordinary building, is built. Deduction employs the Synthetic method. We put together some premisses to see what we can get out of them *taken collectively*. Syllogism means *reckoning all together*. In Induction, our main business is to find causes of effects or effects of causes. Causes and effects, however, do not exist in Nature in isolation. They are found together with irrelevant circumstances. Scientific Induction begins with

disengaging the relevant circumstances from their irrelevant concomitants. This is Analysis.

What about the basis on which the two forms rest? We have said above that all inference is based on the Unity of Nature or Truth. In Induction, reference is mainly made to the External Reality; in Deduction, reference is mainly made to the Unity of Thought. Deductive Logic is based on the Laws of Thought. Here, whatever is self-consistent, is valid. Inductive Logic is based on the Principle of Unity of Nature (or Laws of Universal Causation and Uniformity of Nature). Whatever is in agreement with this principle, is true.

What is the relative certainty of the results reached in these two forms of reasoning? If the premisses in the Syllogism are true, and the reasoning is valid, the conclusion is necessarily true. In Induction, we cannot be absolutely sure of our conclusion. Theoretical certainty which is available in Deduction is out of the question in Induction. What is this difference due to? Some Logicians are of opinion that the foundations on which Induction stands are not quite so secure as the foundations of Deduction. The Laws of Thought are absolutely certain, whereas the Principles of Causation and Uniformity are simply assumed as true. The Laws of Thought are

Axioms; the fundamental principles of Induction are Postulates. Other Logicians are of opinion that the foundations in either case are equally secure or insecure. If we do not place as much reliance on the conclusions of Induction as on those of Deduction, it is because the enquiry in the former case is so much more complex and difficult. We can be sure of the notions of our own creation, but facts are independent of us and may often be misobserved and misinterpreted. We shall revert to this point in a future chapter.

To sum up, the contrast between Deduction and Induction may be expressed thus:—

(i) In Induction, we pass from facts to principles; in Deduction, we pass from principles to facts.

(ii) Induction is concerned with the Matter of Thought, whereas Deduction is concerned with the Form of Thought. *Cf*. their names—Logic of Science and Logic of Consistency.

(iii) Induction mainly employs Analysis, whereas Deduction is synthetic in method.

(iv) Induction is based upon the Principles of Causation and Uniformity of Nature (to be discussed below);

Deduction rests upon the Laws of Thought.

(v) The conclusion in Deduction is absolutely certain, if the premisses are true and the reasoning is flawless; such theoretical certainty is not possible in Induction.

4. The Essentials of Induction.

In this book we shall study Inductive Inference. 'Induction,' says Bain, 'is the arriving at General Propositions by means of Observation or Fact.' 'In an Induction,' he goes on, 'there are three essentials:—(1) the result must be a *proposition*—an affirmation of concurrence or non-concurrence—as opposed to a Notion, (2) the Proposition must be *general*, or applicable to all cases of a given kind; (3) the method must be an appeal to *Observation* or *Fact*.'

The first essential of an Induction is that it is a *Real* Proposition; *i.e.*, it conjoins or disjoins two distinct concepts. This distinguishes it from a definition. A definition may be a general proposition, but it is not real. The Predicate in a definition is already contained in the Subject. An Induction joins to the Subject a Predicate that is not contained in it. The second essential of an Induction is that it is a *general* proposition.

Enough has been said on this point in a preceding section. In an Induction we must go beyond our observations. We must extend the concurrence 'from the observed to the unobserved cases—to the *future* which has not yet come within observation, to the *past* before the observation began, to the *remote* where there has been no access to observe. This is the leap, the hazard of Induction, which is necessary to complete the process. Without this leap, our facts are barren; they teach us what has been, after the event; whereas we want knowledge that shall impart what we have no means of observing. A complete Induction is a generalization that shall express what is conjoined everywhere, and at all times, superseding for ever the labour of fresh observation.' (Bain.) And thirdly, an Induction is based on the observation of facts. When a proposition is derived from other propositions, as in Mathematics, the argument is not Inductive. In Induction our starting point must be facts.

5. Types of Induction.

All Induction is not of the same type or value. Sometimes we simply argue from our experience of the past without analysing that experience. Here we rely upon the existence of Uniformity in our past experience. The greater

the number of instances in which we perceive a connection, the greater is our confidence in the universality of that connection. This Induction is known as **Induction by Simple Enumeration.** In other cases we try to discover in what the instances resemble and base our conclusion on that resemblance. If two things or cases, A and B, resemble in some vital points and a new point x is found to belong to A, we infer that it will be found in B as well. This is argument by **Analogy.** Here there is some analysis, but it is far from being thorough. In **Scientific Induction,** we seek to discover the causes of effects or effects of causes by analysing the complex circumstances and phenomena into their constituent elements and isolating the relevant factors. Whatever can be omitted without affecting the effect is regarded as irrelevant; whatever is indispensable to the production of the effect is accepted as the cause. It is in Scientific Induction that analysis is fully employed.

6. Inductions Improperly socalled.

Besides these, Mill mentions some Inductions, improperly socalled. These are three in number:—(i) The socalled Perfect Induction, (ii) Parity of Reasoning, (iii) Colligation of Facts.

(i) **Perfect Induction.** According to Mill, Generalisation is the essence of the process of Induction. Where we do not go beyond the premisses, there is no Induction. With Mediæval Logicians, however, Induction was only a process of counting particular things, and, on the basis of that counting, asserting something about the class that comprised those things. Their ideal was to count *all* the things. When this ideal was realised, the inference was called a Perfect Induction. When complete examination could not be secured, the induction was called Imperfect. The ground of inference in either case was the number of observations. In the Perfect Induction, the enumeration was complete; in Imperfect Induction, it was incomplete.

Mill attacks both these forms and maintains that the Perfect Induction, which the Mediæval Logicians regarded as the ideal form of Inference, is no more than reassertion of the premisses in an abbreviated form. If I observe that every one of the planets revolves round a central luminous body, and, on the ground of these observations, assert that all planets revolve round a central luminous body, the statement is no inference from the observations. It is identical with them. If all species of animals and all animals in every species are known to possess a nervous system,

there is no inference in maintaining that all animals have a nervous system.

(ii) **Parity of Reasoning.** Having shown that the three angles of the triangle ABC are together equal to two right angles, we conclude that this is true of every other triangle, not because it is true of ABC, but for the same reason which proved it to be true of ABC. Here the characteristic quality of Induction is lacking—the conclusion is not believed on the evidence of the particular instances. 'We do not conclude that all the triangles have the property because some triangles have, but from the ulterior demonstrative evidence which was the ground of our conviction in the particular instances.'

(iii) **Colligation of Facts.** "Suppose that a phenomenon consists of parts, and that these parts are only capable of being observed separately, and as it were piecemeal. When the observations have been made, there is a convenience (amounting for many purposes to a necessity) in obtaining a representation of the phenomenon as a whole, by combining, or, as we may say, piecing these detached fragments together. A navigator sailing in the midst of the ocean discovers land: he cannot at first, or by any one observation, determine whether it is a continent or an island; but he coasts along it, and after a few days finds himself to

have sailed completely round it; he then pronounces it an island. Now there was no particular time or place of observation at which he could perceive that this land was entirely surrounded by water; he ascertained the fact by a succession of partial observations, and then selected a general expression which summed up in two or three words the whole of what he so observed. But is there anything of the nature of an induction in this process? Did he infer anything that had not been observed, from something else which had? Certainly not. He had observed the whole of what the proposition asserts. That the land in question is an island, is not an inference from the partial facts which the navigator saw in the course of his circumnavigation; it is the facts themselves; it is a summary of those facts; the description of the complex fact, to which those simpler ones are as the parts of a whole." (Mill.)

Mill's Inductive Scheme may be laid out as follows:—

Inductions	1. Properly socalled	(*i*) Scientific Induction.
		(*ii*) Imperfect Inductions— Simple Enumeration & Analogy.
	2. Improperly socalled	(*i*) Perfect Induction.
		(*ii*) Parity of Reasoning.
		(*iii*) Colligation of facts.

7. The use of Induction.

Induction has been spoken of as the Logic of Science. It does not pretend to lay down rules for the guidance of the Sciences. Rather it studies the method that the Scientist employs in his work. Just as Grammar records the modes of correct speech, so Induction records the processes that are employed by the man of Science. It should not be supposed, however, that Inductive reasoning is used only in the Laboratory. In every-day life we are almost constantly using it—of course, in a rough manner. In order that we may live, we must know. Knowledge is Power. And no knowledge is more urgently required than the knowledge of causes. On returning from the College, I find that the trunk that I left locked in my room is now unlocked and the contents thrown out of order. I am anxious to know the cause, and, if I reason at all, I employ what may be called a rudimentary Induction. A medical man finds that a patient is feeling very uncomfortable. He is anxious to know the cause of the trouble, because, by eliminating or counteracting the cause, he can hope to remove the effect. Again, a report is made in a court that a certain individual has been robbed. There is evidence tending to implicate Nihal in the affair and there is evidence that tends to show him unconnected

with the affair. The business of the court is to sift this evidence and see whether Nihal has actually committed the offence. These are some instances that should show that Induction is not confined to scientific enquiries properly so called. In the affairs of ordinary life also we are in search of causes and in that search our procedure is not altogether unscientific.

CHAPTER II

OBSERVATION AND EXPERIMENT

1. The Ascertainment of Facts.

An Inductive science has a three-fold function—(1) to ascertain facts, (2) to ascertain causal connections between facts, and (3) to explain these connections and to enunciate generalisations. The second and third functions can be performed only when the first function has already been performed. When there are no genuine facts, it is meaningless to talk of their connections or of the laws according to which they are connected. Facts are the raw material of science. They are the material with which we must start before we can generalise ; they are also the touchstone to determine the value of our generalisations. Whenever a single fact can be found to conflict with a generalisation, the generalisation must be rejected or revised.

Facts can be ascertained only by being observed. We may observe them ourselves, or others may observe them for us. Again, they may be observed with our sense organs as they are, or with the aid of instruments. And thirdly, we

may observe facts as they are presented in nature or we may interfere with the course of nature and see what happens. In other words, we may simply note our facts or first make them and then note them. These are differences in detail—between personal observation and testimony, between observation with unaided sense organs and observation with scientific instruments, between simple observation and experiment. Ultimately, in every case, a sense organ must be impressed by some stimulus. This is how we can observe facts about the external world. Many facts about our own mental life we can observe merely by 'looking within.' To know that I am sorry or angry just now, I need not use any of my senses. I know these facts immediately, by introspection.

2. Personal Observation.

When a photographic plate is exposed to light, it is affected by the rays of light. Our observation is not of this type. My eyes are open, but not every thing that is within the field of my vision is observed by me. So many sounds that are being made now can be heard by me ; i.e., they are loud enough to enter into my consciousness ; but they are not all being actually heard. They do not interest me and whatever

does not interest does not catch attention. When you pass through a street, hundreds of events that happen before you never enter into your experience. *Observation is selective.* Out of a multitude of impressions that *can* be noted at a particular time, only a few *are* noted. This is the first point to be borne in mind in connection with personal observation. Eye-witnesses of a certain occurrence may widely differ with one another, though each of them observed accurately. Each observes only a part, and that is not necessarily the part that others observe. In fact, it would be strange if all observed exactly the same part.

Secondly, *personal observation is fallible.* While we are making an observation, it is difficult to believe that we do not observe accurately. If certainty can be found anywhere, it must be in our sense impressions. This is our natural feeling. And yet we do believe that others are often misled by their senses. About ourselves also, we are ready to admit that in the past we observed wrongly. When a previous experience is in con-
cult to believe that we do not observe accurately.
accept the present experience as the truth and the past experience as an illusion. However, if we erred on a former occasion, we may be erring now. A man suffering from jaundice sees all things yellow. His natural impulse would be to suppose

that his present impression gives him the true colour, and that his former impressions were illusory. If he does not think like this, it is because (1) his impressions do not harmonise with the impressions of others, (2) he is aware that there is something wrong with him, and (3) he expects that previous experiences will come back when the present physical trouble passes away. He has jaundice only now and then. But the fact that while suffering from jaundice he sees things in a different colour, convinces him that for accurate observation sense organs should be functioning properly.

The chief cause of our mis-observing is what may be called mental jaundice. As has been said already, observation is selective and we select according to our interests. The interests of different individuals are different and hence their observations differ. Observation is not merely being stamped passively by an external stimulus. It involves interpretation of the impressions that we receive. This interpretation very largely depends upon our general disposition and present mental condition. This is a bias that affects our observations. Let us take a simple instance. A bird is singing on a hedge. A pious Mohammadan hears in the song *Subhan teri qudrat*. To a Hindu the bird seems to be repeating *Sita*,

Rama, Dasrath. A petty shop-keeper imagines that the bird is only advertising *Dal*, *tel*, *adrak*. A superstitious man will hear in the rustling of the leaves of trees the cries of evil spirits. When nothing is wrong with our organs, misobservation is due to a wrong interpretation. When a man is in an excited state of mind, the liability to misobserve is considerably increased.

We shall refer to these tendencies in detail when we deal with the Fallacies of Induction.

3. The Use of Instruments.

Man is a tool-using animal. And this use of tools enables him to control nature and the lower animals. A man who protects himself from a rabid dog by means of a stick or a stone, behaves in a way which is not open to any lower animal. For his present purpose he elongates his arm and makes a part of it invulnerable. For his sustenance he does not depend upon the mere goodwill of mother earth ; he ploughs the land and compels the earth to yield him the food that he wants. If he finds that bulk for bulk he is heavier than water, he rides a wooden plank and thus crosses a stream. Instruments stand him in good stead in securing control of natural forces. Instruments perform another function in the ser-

vice of man. They enable him to observe better. With their aid, things that would otherwise escape detection are observed. By a telescope we may be enabled to see the heavenly bodies that are invisible to our unaided eye. The photographic plate may record impressions that otherwise remain unnoted. A man with defective powers of hearing hears with the help of an ear-drum sounds which are otherwise inaudible. Secondly, instruments enable us to observe more accurately. With their aid we can notice slight variations which otherwise remain undetected. A nice balance will show very small differences in weight, differences which would be quite imperceptible to our muscular sense. A thermometer gives a far more accurate record of temperature than our skin can give. A barometer is a more reliable index to the atmospheric conditions than our organism can be. By the use of a stethoscope a doctor knows about the working of the lungs much better than he can know by his unaided ears.

4. Experiment.

But whether we use our sense organs unaided or with some instruments, the facts that we observe are *found* in Nature. We do not *make* them. The conditions under which observations

are made are determined by Nature. When we determine the conditions ourselves, the observation is performed under more favourable conditions and is called an Experiment. Experiment is not a method of a different type for ascertaining facts : it is observation performed under conditions that we have introduced, because thus alone can we observe best for our present purpose. In observation, we concentrate our attention on certain aspects of the phenomenon. As has been said above, all observation is selective. In experiment this selection of certain aspects or analysis is carried further. The aim of Inductive enquiry is to establish a causal connection between facts, and Inductive sciences that are in an advanced state all depend upon experiment.

Wherein lies the superiority of Experiment over Observation? 'Experiment,' says Mill, 'is an immense extension of Observation. It not only enables us to produce a much greater number of variations in the circumstances than Nature spontaneously offers, but, also, in thousands of cases it produces the precise *sort* of variation which we are in want of for discovering the law of the phenomenon. . . . It enables us to obtain innumerable combinations of circumstances which are not to be found in Nature ; and so add to Nature's experiments a multitude of experi-

ments of our own.'* We find that we can sustain our life only in the air. Air is a compound, and it may be our business to find the particular constituent in it that supports life. Nature does not show these elements in isolation. Experiment enables us to analyse the air into its component parts and immerse a living animal into each one of them and the various combinations into which they can enter. Thus, we can find which one of these elements singly or in combination with some others supports life.

Another advantage that Experiment possesses over Observation is that we can isolate the phenomenon under investigation and observe it in the midst of circumstances with which in all other respects we are already accurately acquainted. Lightning is electricity. The observation of thunderstorms would be quite incapable of yielding even a fraction of the knowledge that has been obtained by experimenting with electricity produced in the laboratory. 'In lightning, electricity was too intense and dangerous; in other cases it was too feeble to be properly understood. The Science of Electricity could only advance by getting regular supplies of electricity from the common electric machine or the galvanic battery.' (Jevons.) In Nature some processes are so slow

* Logic : III, vii, 3.

that we may have to wait for centuries to meet with facts which we can readily produce in a laboratory. How long should we have to wait if we were to depend upon simple observation to know the composition of water?

But though Experiment is a more potent instrument of Inductive enquiry, Observation is not altogether valueless. In some cases, Observation alone can be employed; in others, it is to be preferred to Experiment. In investigating a causal connection, our object may be to find the cause of an effect or the effect of a cause. When the effect is known and we are in search of its cause, we have to depend upon Observation. 'We can take a cause and try what it will produce; but we cannot take an effect and try what it will be produced by. We can only watch till we see it produced or are enabled to produce it by accident.' (Mill.) In Geology, Botany, Astronomy, History and Sociology, we mainly depend upon Observation. If we are anxious to know the effect of early marriage on the intellectual vigour of a people, we might experiment upon a people in which early marriage is now non-existent. This, however, would be a dangerous experiment. We should observe the case of the people who are in their ignorance marrying in childhood and compare them with other people. If our object is to know

something about the solar eclipse, we must wait till the eclipse does occur. We cannot produce the phenomenon. On the part that Experiment and Observation now play in the various sciences, the following paragraph from Mellone well summarises the whole position :—" Without experiment Mechanics, Physics, and Chemistry could scarcely exist ; and these are fundamental Sciences in an advanced state. In Physiology, experiment naturally plays a much smaller part ; for, if made, at all, it has to be made on the organs of the living body. In the sciences of description and classification,—Botany, Zoology, Mineralogy, —the range of experiment is still more restricted ; while in Astronomy, Geology, Meteorology, we may say that experiment, as far as we are concerned, is impossible. We say ' as far as we are concerned,' because nature sometimes produces phenomena of so remarkable a character, that she may be said to be making an experiment herself —as in an eclipse of the sun." *

5. Rules for the Regulation of Observation.

Before closing the chapter, we may mention the rules that may be laid down to regulate observation :—

(1) In the first place, we must be sure

* Logic : 293-4.

that we observe and are not inferring. Mere Observation and Inference so often and so readily mingle with one another that it needs a great effort to keep them apart. Most people would say that they see the sun moving from the east to the west; whereas what they actually see is a change in the relative position of the sun and the part of the earth on which they stand. This change can be accounted for by the movement of the earth from the west to the east, or by the movement of the sun from the east to the west, or by both these movements taking place together. In every perception, there is an element of interpretation. When we misinterpret an impression, we get a false perception or illusion. In making observations, it is of the utmost importance to keep simple observation and inference apart.

(2) Where a single observation would be misleading, we should note a number of cases and get the average. The average itself is liable to error, but the individual observations are far more liable. The errors on one side will cancel those on the other, and consequently the mean will be nearer the truth than the extremes are.

(3) We have said that all observation is selective. This means that in observing we concentrate our attention on certain aspects of the whole complex phenomenon and ignore the

remaining aspects as irrelevant for our present purpose. From this it follows that if observation is to be of any use, only material points should be noted. A medical man who has been summoned to examine a patient will note the condition of his lungs, heart, stomach and other organs, but will not care to count the teeth of the patient or measure his height. He will look to the sanitary condition of the house; he will see whether it is properly ventilated; but he will not, at least should not, waste his time in counting the beams in the ceiling or the nails in a window. It should be borne in mind, however, that the distinction between the material and the immaterial among the aspects of a phenomenon is very difficult to draw. For centuries the appearance of comets was regarded as a very relevant circumstance about wars and some even now do not look upon it as altogether irrelevant. The conjunction of the stars at the time of the birth of a man is by many regarded as a material circumstance that determines his career. After analysis has been performed, the main task is to disengage relevant circumstances from the irrelevant ones. The Inductive Methods, to be described hereafter, are used to effect this disengagement.

(4) The phenomenon to be observed should be noted under varied circumstances. If I am

anxious to know the effect of quinine on malarial fever, I should administer it to malaria patients of various ages, belonging to various walks of life, and living in various localities.

(5) The phenomenon under investigation should be examined in isolation, so far as it be possible. Unless this is done, we cannot be sure that interfering conditions are not present. Some patients prefer using a number of prescriptions simultaneously. In such cases, it is illogical to ascribe the cure to the use of any one prescription, or, if there is no cure, to suppose that none of the prescriptions is efficacious. A clerk who was anxious to supplement his income advertised a medicine that would prove panacea for all ills. In cases of fever it was to be taken with quinine, in cases of constipation with castor oil, and so on. That it should never be taken alone was in the interest of the 'doctor,' and perhaps it was not much against the interest of the patients either, for the thing was probably quite harmless, but, in so using it, it was impossible to find out what *it* was worth.

These rules can be better observed in Experiment, i.e., in Observation conducted under conditions determined by ourselves.

CHAPTER III

CLASSIFICATION AND NOMENCLATURE

1. Nature and Use of Classification.

Classification is the process of arranging a number of objects into kinds or groups, characterised by the possession of common marks. It is very intimately related to division and by some Logicians is regarded as identical with it. Fowler defines it as ' a division or a series of divisions and sub-divisions.' But in division, as the name itself implies, we start with the entire group and proceed downwards. In classification we go upwards, we sort the miscellaneous lot into classes, and these classes again into higher classes. This process, as Venn suggests, may more appropriately be called Aggregation.

The sub-classes into which a class is divided are mutually exclusive and collectively exhaustive. There must be no ever-lapping and every thing must find a compartment for it. In classification, there may be individuals which seem to fall between two classes or under each of them. In a Library there will be a section for History and another for Philosophy. Where shall we

place books on History of Philosophy or Philosophy of History? In Nature we sometimes find organisms which can be regarded as plants as well as animals.

And when we have got a classification, it is nothing final; its results are provisional. New species may be discovered, characters that are supposed to be incompatible may be found to be compatible and *vice versa*. This shows that the work of classifying things is far more difficult than formally dividing a genus into species.

Man is naturally inclined to find order or produce order in the bewildering multiplicity of things by which he finds himself surrounded. Every general name that we use points to a classification. When I speak of the dog, I have classified all things or animals into two groups—dogs and non-dogs, and the individuals that I call dogs have been put together on the basis of some common characteristics. As Venn puts it, 'ages before the logician, or any one else who deals with systems, had a hand in the matter, the necessities of common life had been at work prompting men to group the things which they observed. All names imply the recognition of groups, and a great number of names imply a subordination of groups, so that at the earliest stage to which we can transfer ourselves we find that we are already

in possession of rudimentary classification ; and that we cannot even talk or think about the things without an appeal to this.'*

Classification has been spoken of as a grouping of things together on a basis of common features. This grouping may be actual or only mental : that is, we may juxtapose and separate space-occupying things or may only form systems of ideas. In a museum or a library we arrange actual things ; in a census register we arrange not men but their names. Even after the census, men continue to be mixed up. In Botany, our object is to classify plants mentally, in Psychology we classify mental states.

Let us first study the process as used in practical life.

2. Classification in Practical Life.

To a student, the word 'class' naturally suggests the group of which he himself is a member. A 'class' is a class of students. Why are students classified at all? Plainly, because they are so many and differ in some material points. The Principal wants to make the most of his opportunity : he is anxious to develop the minds of the young men placed under his care.

* Empirical Logic : 372.

They must be sorted on some basis that is relevant to his purpose. Men who are almost on the same intellectual plane are put together. The Matriculation Examination is a device to divide the students reading in the high class into two classes. Those who are fit to enter upon the University course are the successful group. In the college similar tests are used again, at the Intermediate and B.A. Examinations. This is the preliminary act. Again, the University allows a certain amount of choice of subjects to students at the same stage. Students are grouped into Philosophy, History and Science classes. If practical convenience requires, science men are again arranged into groups for practical work.

This roughly gives us one classification of students. Its basis is instruction in the narrow sense of the word. However, in a college 'instruction' is not the sole business. Students are also grouped for games. We form cricket, football and hockey elevens. The Ashramas and blocks in the Boarding House give yet another classification. The students themselves may form literary or religious associations.

These classifications show that a miscellaneous lot may be arranged in several ways, and that the same individual may belong to several groups. In every case, the classification is per-

formed with a certain end in view, and, in consequence, with the change of that end, the classification also changes.

An excellent illustration of classification in the service of a practical end is furnished by a college library. Besides the books that the students possess individually, the college as a corporate body possesses several thousands of volumes. They are meant to be read by students and teachers, and in order that this aim may be realised they must be arranged in some order. If they were lying in a heap, one could hope to find a particular book only on a holiday and that also after doing some damage to other books. A library is not merely a collection of books, but a collection arranged according to some plan. According to what plan are they arranged? As was said in the very beginning, classification is grouping things together on the basis of some common features. Now books may resemble each other in size, in price, in the colour of their covers. Several of them may have been written by a particular author or published by a particular house. None of these should appeal to a sensible college librarian. For his purpose, the basis of classification is the subject-matter of the books. Accordingly, we have a college library divided into sections—Dictionaries and Cyclopædias, Philosophy,

Physical Science, Mathematics, History, Literature, &c. These sections are again subdivided. Literature may be divided into General Prose, Poetry, Drama, Fiction, Biography, Criticism, &c. Philosophy may be divided into Metaphysics, Psychology, Ethics, Logic, Æsthetics, History of Philosophy. Books that should be near each other on account of their affinity in respect of their subject-matter should be brought together. This is the main principle of arranging books in a library. Books differ from one another not only in their subject-matter but also as regards the language in which they are written. As ordinarily a man understands only one language well enough, books are also classified on this basis. This division is prior to the division according to subject-matter. For ready reference every decent library also possesses an alphabetical catalogue arranged according to the names of the authors. Such a catalogue also enables a reader to study a particular author who may have written on various subjects. This catalogue, however, can be only a supplementary reference book. In the sub-divisions that we arrive at by classifying according to subjects, if the number of books in a particular sub-division is fairly large, we have to fall upon the alphabetical arrangement.

The arrangement of books in a depot or a pawnbroker's shop may be on a different plan.

Another illustration of the process of classification as applied in practical life is furnished by the classification of convicts. Some people prefer to live by crime rather than by honest work, and if they are sent to prison again and again, they find the place as congenial as their homes. It is important that the state should be able to identify such persons. They can without difficulty change their name and generally give wrong information about their place of birth and other similar particulars. However there are certain features of their persons which they cannot change, and, on the basis of these features, it is possible to classify all convicts that are once sent to prison and to identify them at the time of a second conviction.

M. Bertillon, a Frenchman, devised the following system.—He found that after manhood is attained, the length and breadth of certain bony parts of the human body, five in number, seldom increases or diminishes. For practical purposes they remain invariable. And these measurements are never found to coincide in case of any two individuals. They are least correlated to each other, i.e., if two individuals agree in respect of

two of these measurements, it does not follow that they will agree in respect of the remaining three measurements also. These five invariable features are:—(a) length of the head, (b) width of the head, (c) length of the left middle finger, (d) length of the left forearm, (e) length of the left foot. These organs may be long, of medium size or short ; and the head may be wide, medium or narrow. Height, colour of the eyes and the hair, complexion and any other distinctive marks are also noted and the convict photographed. The classification is mainly based on the five principal measurements. Convicts are first classified as tall, medium sized and short. Each of these classes is then divided into long headed, medium headed and short headed ; and so on. After a few minutes' observation of the features of a convict, you can go straight to the small packet where, if anywhere, his photograph must be found.

This system was for sometime used in India, but it is now replaced by Galton's system of finger-prints. Galton is of the opinion that the chance of two finger prints being identical is less than one in sixty-four thousand millions. And it is obvious that a finger-print can be obtained more easily than Bertillon's measurements.

3. Classification in Science.

The business of Inductive Science is to find connection of co-existence or causation between facts. In order that this may be done, it is essential that facts be marshalled in some order. Only thus can we control our facts. Classification is not an Inductive Method, but a process subsidiary to Induction. Again, there are some sciences in which Laws of Causation, in the present state of our knowledge, cannot be established. All that can be attempted in them at present is to arrange things according to their affinities, and derive some generalisations from such arrangements. These sciences are Botany, Zoology and Mineralogy. The classifications of Botany and Zoology are very complete, and this is due to the fact that the number of things demanding an arrangement is very large and very few laws of causation about plant and animal life have so far been discovered.

What is the basis of classification in these sciences? If we classify animals according to the initial letters of the names that we give them, the classification will not indicate any affinity amongst the animals themselves. If we choose colour as the basis of classification, the classification will not be of much scientific value, for the mere fact that an animal is black does not tell us anything about its essential nature. The primary

object of a scientific classification is to enable us to know something about the origin, structure and affinities of an animal or a plant. If a classification serves this purpose, it is Natural: otherwise, it is Artificial. To put the same thing in another form, a Natural classification is based upon a number of essential characters, whereas an Artificial classification is based on a single attribute or a small number of attributes.

According to Mellone, a Natural classification should satisfy the following conditions:—

(a) It shall enable the greatest number of general assertions to be made about the class.

(b) It shall enable us to infer of any other member a great part of what we know about any one.

(c) Its members shall have the greatest number of points of mutual resemblance, and the fewest points of resemblance to members of other groups.

All this is secured if we base the classification upon *important* characters. Now what is an important character? A character is important with reference to a certain end and the end in science is general knowledge about the

essential nature of an object: knowledge, that is, about its origin, structure and affinities. Fowler proposes the following criteria for the purpose of discriminating between the more and the less important properties of natural objects:—(1) A character which is found to furnish an invariable index to the possession of certain other characters is of more importance than a character which furnishes no such index. Thus, the internal structure of an animal is of more importance than its size, and the mode of fructification of a plant than the colour of its flowers. (2) Amongst such characters a character is regarded as of more or less importance according as it accompanies a greater or a smaller number of other differences.

4. The Theory of Evolution and Classification.

The Theory of Evolution teaches that all animals may be regarded as members of one family : some are, so to say, first cousins, others second cousins, and so on. That character is important which indicates, in the literal sense of the word, the affinities of the animal, i.e., its family relationships. The doctrine of evolution supplies the principle of community of descent as the binding thread for scientific classification. ' Under the influence of this conception the aim of classification has been completely revolutionized.

Whereas formerly the realm of organic life was assumed to consist of a definite number of species which could be separated from one another by definite marks until the whole number of species had been enumerated and described, now, as it exists at any given moment, it is considered rather as the result of descent from a common ancestry with the modifications which successive ages have witnessed. The ideal for the older classifications was that of formal division in which the highest genus was so divided that the sub-classes were mutually exclusive and at the same time co-extensive with the whole; the aim for the newer is rather the construction of a genealogical tree which will just as surely include every member of the family.'* This means that in nature there are no 'natural kinds.' The species of animals or plants are not separated from one another by impassable gulfs. There is continuity in life and the more surely a character indicates community of descent, the more important it is.

5. The Value of Classification.

The value of classification in science has already been indicated.

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* Welton and Monahan: Intermediate Logic, 88.

(1) It arranges facts and thus facilitates their study.

(2) It aids the work of discovery. When several things have been put together, their comparison reveals new properties. What we observe about a particular individual, is likely to be found in others.

(3) Where causal connection cannot be inductively established, Classification enables us to get some generalisations. Even in sciences in which causal connection can be established, classification is an important preliminary step.

6. Nomenclature and Terminology.

The business of Science is not to classify things actually but to systematise them mentally. Inductive Logic, as the study of the principles of scientific investigation, is interested only in the ideal classification. This classification, in order that we may use it again, or others also may use it, must be fixed by technical terms. Technical language is essential to science and consists of Nomenclature and Terminology. Nomenclature of a classification consists of the names of groups systematised by the classification. Terminology consists of words which describe the properties of a group or an individual member of a group. Botany, Zoology and Chemistry furnish good

examples of Scientific Nomenclature and Terminology. The kingdoms, sub-kingdoms, classes, orders, families, genera, species and varieties of animals have all been assigned definite names. The general plan is to combine the name of a higher group with a characteristic that is found only in a particular part of it. This is like definition by genus and differentia. In Zoology or Botany, however, it is not necessarily the differentia that is chosen as the characteristic element in the name. Rabbit is called *Lepus Cuniculus*; the common hare, *Lepus timidus*. The field Rose is called *Rosa arvensis*; the Dog Rose, *Rosa canina*. Chemical Nomenclature seeks to indicate the composition of compounds and their relation to one another. We have Carbon monoxide and Carbon dioxide ; Sulphur dioxide, Sulphur trioxide and Sulphur sesquioxide. Then in combination with other elements, Sulphur forms *sulphides*, *sulphites* and *sulphates*.

Chemistry also employs symbolic nomenclature. H_2O (water) means two parts of Hydrogen combined with one part of Oxygen; H_2SO_4 (sulphuric acid) is a compound of Hydrogen, Sulphur and Oxygen, mixed in certain proportions. Copper *sulphide* is CuS, Copper *sulphite* is $CuSO_3$, and Copper *sulphate*, $CuSO_4$.

No class or individual can be described un-

less there be terms for every part and every property of it. Botany, Zoology and Chemistry have got excellent terminology. The Biologist and the Chemist can almost draw their objects in words. Various branches of Philosophy (Psychology, Logic, Epistemology) and Law also have a fairly large number of technical terms. In law, understanding the precise meaning of legal terms is as important as a comprehension of the fundamental principles.

Some terms form part of the technical language of more than one branch of knowledge. Take, for instance, the term *Mood.* In Grammar, it stands for the mode or manner of the action expressed by the verb. In Logic, Mood stands for a syllogism considered from the point of view of the quality and quantity of the propositions that constitute the syllogism. Thus we speak of the Moods AAA and EIO. In Psychology, Mood stands for the effect of an emotion that persists for sometime after the emotion itself has passed away. When we receive a piece of good news, for hours afterwards every event tends to take on a bright colouring ; we are in a jolly mood. Similarly, the terms Figure and Extension mean in Logic something quite different from what they mean in Mathematics.

CHAPTER IV

GENERALISATION

1. What is Generalisation ?

We have seen that facts are the raw material of Science. They are also the touchstone whereby we test the value of a theory. A science, however, is nothing if not a body of generalisations. Facts are particular occurrences ; generalisations are universal propositions which are based on those particulars. Inductive science begins with particulars and establishes universals. I see that a particular stone, when I let go of it, falls to the ground. This is a particular observation. I generalise this observation when I say that all stones if thrown into the air will fall to the ground. I see that fire burns my finger. I also see that fire burns a piece of paper that I throw into it. It is a particular fire that I have observed in each case. On the basis of these observations, I generalise and say that fire, wherever it is, burns a finger or a piece of paper. My statement is not confined to any particular finger or piece of paper. Our observations, whatever be their number, must be particular facts. Induction

builds upon them. One of the essentials of Induction is that it gives us a general proposition as the result of comparison of facts.

2. Kinds of Generalisation.

A generalisation, if it is to be of any scientific value, must be a valid generalisation. The human mind is prone to generalise rather too hurriedly. A man leaves his house and some one sneezes. The man encounters a mishap and generalises that whenever in future some one sneezes at the time of his leaving his house, all will not be well with him. Science demands that some causal connection be discovered between the two facts that we affirm will always be conjoined. Even if in every case that comes under our notice, the two facts are found conjoined, we get only an Empirical Generalisation. We know, that is, that so far as our experience goes, these facts are conjoined: we do not know, however, *why* they are conjoined. When this explanation is available, the Generalisation ceases to be empirical. It becomes a Law.

3. The Basis of Generalisation.

These are the two kinds of valid Generalisation, or better two stages through which Generalisation passes. Into the characteristic features of

these two forms, we shall enquire in a future chapter. Here we shall enquire what right we have to generalise. That we do generalise is a *psychological fact*. Logic must tell us what, if any, ground there is for our passing from the particular to the universal. As has been said before, we are interested in facts not only for their own sake, but also, and perhaps primarily, for the sake of other facts to which they point. All facts are parts of a system. Nature is a Unity. This is the fundamental supposition on which generalisation rests. Further we generalise because we suppose that every effect can be referred to some condition or other that is indispensable to its production. These two presuppositions—Unity or Uniformity of Nature and Universal Causation are the basis of all generalisation. If nature were not uniform and events were to jump out of non-existence without any cause, life would not be possible. And certainly no reasoning would be possible. Nature is intelligible only because there is order in it.

4. Generalisation and Perfect Induction.

Before we pass on to a discussion of these presuppositions of Inductive Science, we must mention a negative determination of Generalisation. There is no Generalisation if the universal is

a summary of a number of particular statements. To use technical language, the socalled Perfect Induction does not involve any Generalisation. In Perfect Induction we do *not* pass beyond our premisses. In Generalisation we *must* pass beyond them. It is only Imperfect Induction—the Induction in which all the instances have not been counted—that possesses any scientific value.

CHAPTER V

THE LAW OF CAUSATION

1. What is a Cause?

Aristotle speaks of four kinds of causes. These are Material, Efficient, Formal and Final. Let us suppose that a potter makes a pot. The clay is the material cause of the pot. It is the stuff or matter which assuming a particular form *is* the pot. The potter himself is the efficient cause. His is the force or power that brings the pot into existence. But how is it that the energy of the potter turns the clay into a pot and not a sphere or a toy? The image of the pot rather than that of the sphere or the toy was present in the potter's mind when he set to work. It is the form of the pot that he meant to give to his material. This image of what he wants to produce is the formal cause of the pot. Again, a conscious agent works for a certain *end*. The purpose for which the potter expends his energy in this manner is the final cause of the pot. The potter may make the pot to earn his living, or

to provide himself with a useful article for his forthcoming trip, or to give it away to a Brahmin for the spiritual benefit of his ancestors.

In the Mediæval times, the essence of the cause was considered to lie in its power or efficiency. Cause meant the efficient cause. This idea, *viz.*; the cause is a force or power that produces the effect, remained undisputed throughout the middle ages. Locke (1632—1704) who effected a revolution in Philosophy by making experience the basis of all knowledge left the idea of Power unassailed. He speaks of it as a simple idea. **Hume** (1711—76) criticised the notion of efficiency. How do we get the idea of a causal connection? Sometimes this connection is observed between two external phenomena; as, fire burns a piece of wood; the heat of the sun melts the snow; the wind blows away a leaf. Sometimes we observe this connection between our own will and the movements of our body, and, through these, of other bodies. I will that my finger should move and it moves. I will to express an idea and forthwith my lips utter sounds. When I choose to drink a cup of water, my hand moves and, through this movement, the cup is lifted from its place to approach my mouth. Lastly, we observe this connection between our will and our ideas. I desire to summon the image

of my brother and the image rises before my mind. I desire it to remain there, and for sometime it does remain there. Now Hume maintains that in none of these cases is there any consciousness of power. What is observed is merely a sequence of phenomena. A particular event occurs and then another event occurs. *The essence of causation lies in this sequence.* All events, says Hume, are simply conjoined; they are not connected. There is no necessary bond between them; only they happen to come in a certain order. The cause does not *produce* the effect; it simply *precedes* the effect.

However, if we consider any phenomenon, we shall find that the phenomena that go before it are innumerable. Which of these antecedents is the cause? Hume's answer is that the phenomenon that *invariably* leads to the appearance of the effect is the cause of the effect.

This position has been accepted by all the sciences. *From the scientific point of view, the cause is not an agent, but an antecedent phenomenon. The fundamental characteristic of the cause is that it is invariably followed by the effect.*

It may be objected that the day invariably precedes the night and January invariably precedes February; and yet we do not call the day

the cause of the night, nor January the cause of February. **John Stuart Mill** (1806—73) accepted the main position of Hume as regards the phenomenal nature of the cause, but introduced a refinement. He maintained that the cause must not only invariably lead to the effect, but must also do it, whatever other conditions may be. The cause of an event is its unconditional invariable antecedent. Another point on which Mill lays emphasis is that in considering the cause of an event, we should not confine our attention to a single condition that may appear conspicuous ; we should try to find all the conditions that are essential to the appearance of the effect *The cause is the sum-total of the conditions that invariably and unconditionally lead to the effect.*

In recent times, quite a new conception of the causal connection has found favour with scientists. It is maintained that the sum-total of energy in the Universe is fixed ; it can be neither increased nor decreased. All change is due to a transformation of this energy. The amount of energy in the new form is exactly the same as before the transformation. The cause does not produce the effect, nor does it simply precede it ; it develops into the effect. This is known as the doctrine of **Conservation of Energy.** If we were to consider the affinities of this doctrine, we should

say that it allies itself to the ancient view of causation inasmuch as it emphasises efficiency rather than sequence as the fundamental aspect of the causal relation. Strictly speaking, however, the cause and the effect are not two *distinct events* but only *distinguishable aspects* of the same phenomenon or different stages in the same process. When work is done, energy is converted from one form into another, and in this conversion nothing is lost or created.

Motion, heat, and chemical force are three prominent forms of physical energy, and we can find simple illustrations of the Persistence of Force in respect of these forms. Take Motion and Heat. Rub your hands against each other and they will be heated. Hammer a piece of cold iron and it becomes hot. Astronomers are almost agreed that the high temperature of the sun is due to the collision of enormous masses brought together by gravity. Then heat produces motion. A very simple illustration is the work done by a steam engine. Physicists have accurately determined the quantitative equivalence of these two kinds of energy, and found that energy spent in raising the temperature of a pound of water by 1° centigrade is equal to the energy required to lift 1,390 pounds one foot high. When oxygen and carbon combine (when a piece of charcoal is burnt),

the force of combination appears as heat. And conversely heat is used as a means of decomposition of compounds.

To sum up: There are three different views about the essential nature of the cause. According to the first, the cause is an agent that produces the effect ; according to the second, the cause is the sum-total of conditions that invariably and unconditionally lead to a certain effect ; according to the third, the cause is the earlier phase in the development of a process.

2. Development of the Sequence View of Causation.

Whether the cause is an agent or a mere phenomenon is a metaphysical question. Whether we agree with Hume or vote against him, our position as Logicians remains unaffected. Our principal question is—How is it that we can generalise from particular cases? What is our warrant for drawing an Inductive Inference? The inner nature of the cause is not a relevant question with us. Again, when we talk of the equivalence of cause and effect, we are really considering how the causal relation expresses itself. We consider causation in its phenomenal aspect. This is a question for the Physicist and not for the Inductive Logician. For the Logician

the problem is to find the ground of Induction. As we have said above, he has to discover what justification we have to generalise or draw inferences from particular cases. From the logical point of view, the characteristic feature of the causal relation is the invariable sequence between the cause and the effect.

This view, as has already been indicated, has had a natural development. Venn notes three stages in this evolution:—

"There is, firstly, the rude popular view which lends itself to most of the inductive reasoning not only of the savage but also of the 'plain man,' or the uncultivated classes, to this day. There is, secondly, the amendment of this view represented by the logicians and physicists of the type of Hume, Brown, Herschel and Mill. It is substantially, we must insist, the same view as the popular one: though in several respects it marks a great advance in the way of scientific precision. It lends itself to the bulk of what may be called the careful reasoning of practical life, and to the methods of popular science. And, thirdly, there is a refinement upon the last which has been more lately introduced by some thinkers. This view endeavours to guard against certain more or less obvious flaws in the two preceding accounts; but in doing this, *viz.*, in striving to

express the law of sequence with rigid precision, it renders the law suitable only for hypothetical conclusions, in other words renders it useless for positive inductions about matters of fact."*

In the popular view, no difference is recognised between co-existences and sequences in respect of character or importance. **A** will suggest **B**, whether **B** follows **A** or is found with **A**. 'The red colour of the strawberry is looked upon as a sign of its being both soft and wholesome and no distinction would be recognised between the nature of one of these intimations and that of the other. But redness and softness are co-existences, in any natural sense of the word, whilst wholesomeness is entirely determined by the subsequent consequences.' Again, when dealing with sequences, the popular view singles out one antecedent and one consequent and regards them as causally related. A man suffering from fever is cured by the use of quinine. As a matter of fact, other elements besides the use of quinine have been operative in the cure of the man—he is now in a quieter place, gets better diet and has the benefit of pleasant company. The effect also is not simply the disappearance of fever. The cause and the effect are both complex, but the popular view

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* Empirical Logic : 51-2.

singles out one element in each of them, and ignores the remaining elements.

The practical scientific view remedies these defects. According to this view, invariable sequence is of greater logical significance than co-existence. Inductive science aims at discovering Laws of nature and these are assumed to be causal Laws. The practical scientific view insists on taking into consideration all the elements which make up the antecedent or cause. For it, cause is the *sum-total of conditions* essential to the production of an effect. 'It is very common,' says Mill, 'to single out one only of the antecedents under the denomination of Cause, calling the others merely Conditions. Thus, if a person eats of a particular dish, and dies in consequence, that is, would not have died if he had not eaten of it, people would be apt to say that eating of that dish was the cause of his death. There needs not, however, be any invariable connection between eating of the dish and death ; but there certainly is, among the circumstances which took place, some combination or other on which death is invariably consequent ; as for instance, the act of eating of the dish, combined with a particular state of present health and perhaps even a certain state of the atmosphere ; the whole of which circumstances perhaps constituted in this

particular case the conditions of the phenomenon. The real cause is the whole of these antecedents; and we have, philosophically speaking, no right to give the name of cause to one of them exclusively or the other.'* As we have seen above, Mill also insists that the cause will be the unconditional antecedent of an event. Now in order to secure all the elements that constitute the cause, it is necessary that the sequence be as close as possible. If a considerable interval of time separate two phenomena, we cannot be certain of their causal relation. The scientific view amends the popular view by demanding that the sequence shall be as close as possible.

The speculative view amends the popular view and attemps to refine the concept of causation still further. It insists on enumerating all the elements in the antecedent, and demands a similar analysis of the consequent. That is, it is not satisfied that only one element be singled out of the whole consequent and be designated the effect. A consequence of this refinement will be noted in the next section. The speculative view further is more rigid than the practical scientific view in the demand that the sequence be very close. For it, the cause *immediately* precedes the effect.

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* Logic : III. V. 3.

Using symbols we can briefly express the main difference between these views thus:—According to the popular view, a is the cause of x. The practical scientific view amends this by saying that A is the cause of x, A being a complex in which a is one element operating with some other elements. The speculative view amends the statement still further and says that A is the cause of X, where not only A is a complex of many elements, but X is such a complex, and A and X are continuous.

3. Causes and Conditions.

As we have seen above, popular thought makes a distinction between causes and conditions. It is usual to single out one of the antecedents under the name of cause and to call others merely conditions. Mill maintains that, philosophically speaking, we have no right to make such a distinction. The cause is the entire assemblage of antecedents essential to the production of the effect. From the practical point of view, however, the distinction is of some use and we may briefly note its character. To begin with, we should distinguish between *positive* and *negative* conditions. When we light a fire, the lighted match is applied to the fuel. However, the application of the match can produce the desired

effect only if there be some oxygen surrounding the fuel and the wood be not very wet. The presence of oxygen is a positive condition and the absence of moisture is a negative condition. A person, who is ill, is cured by the use of proper medicine. The use of the medicine, however, must be supplemented by proper nourishment and absence of disturbance. Ordinarily only positive conditions are mentioned and the negative conditions are summed up under one head, namely, the *absence of preventing or counteracting causes*.

Now which of the positive conditions is singled out as the cause? Often it is 'that one condition, the fulfilment of which completes the tale and brings about the effect without further delay.' It is that one of the antecedents that comes just before the effect. A patient who is living in a healthy quarter, is properly nursed, and is looked after by a competent doctor, is cured of his disease. To what does he ascribe his cure? Suppose that he has been under the treatment of this doctor and nursed by the same nurse for a fortnight, but has been in the present house only for two days. In all probability, he will ascribe the cure to the hygienic condition of his present rooms. If he has been in this place for a long time and nursed by the same nurse throughout, but has only recently come under this

particular doctor's treatment, the doctor gets the credit for the cure.

It must not be supposed, however, that the condition which came last into existence is always dignified with the name of the cause. The choice of the condition that is denominated the cause is quite capricious, and, as Mill points out, 'however numerous the conditions may be, there is hardly any of them which may not accord to the purpose of our immediate discourse, and obtain nominal pre-eminence. And in practice that particular condition is usually styled the cause whose share in the matter is superficially the most conspicuous, or whose requisiteness to the production of the effect, we happen to be insisting on at the moment.' In the example given above, the doctor will ascribe the cure to his own correct diagnosis, the nurse to her own careful nursing and the owner of the house to the hygienic condition of his house. Even if they do not ignore other conditions, they will apportion the credit for the cure in different ways.

4. The Law of Causation.

We have considered the notion of cause in some detail, because this is the fundamental notion in the whole theory of Induction. The business of all Inductive science is to establish causal

Laws on the basis of causal relations. Inductive science presupposes that **every event has a cause.** Every consequent is connected with some particular antecedent, or a set of antecedents. When Cause and Effect are regarded as particular manifestations of Energy, we further postulate that they are quantitatively equal. (Conservation of Energy.) That the connection between Cause and Effect is uniform is another assumption of Induction. This we shall discuss in the next chapter.

CHAPTER VI

UNIFORMITY OF NATURE

I. The Unity of Reality.

We have seen that the possibility of our inferring what we have not experienced from what we have experienced, or reading observed facts forwards or backwards, is grounded on the assumption that nature is not a chaos but a system. In the present chapter we shall analyse and examine this conception at some length.

Now that I am working at my table, I find before me a few books, an inkpot, a piece of blotting paper, the case for my glasses and a pair of scissors. These things happen to be there together, but is it essential that they should be together? I take up the pair of scissors and put it down on the stool by my side. The books, the case, the blotting paper and the inkpot seem to be unaffected by the removal of the scissors. I take out my watch from my pocket, and remove a part of its mechanism. The watch refuses to work or work properly. Here the rest of the watch does mind the removal of a part. The watch is not an aggregate of independent things

that are merely juxtaposed ; it is a whole of interdependent and co-operative parts. Again, consider my body. The scissors fall on my foot and it begins to bleed. Can the remaining parts of the body be indifferent to what has happened to the foot? No ; the eyes and the hand cannot continue their work with the manuscript. I must attend to the foot. If the injury is serious, I must go to a medical man and get the wound washed and dressed. The eyes, the hands, the tongue and other organs cannot say that it is the foot's concern and they need not worry about it. The human body is an *organism* in which the parts live not for themselves, but for the whole. The parts of a mechanical whole possess in their individual capacity a significance that the organs of an organism do not possess. The mechanical whole works to realise an end that is fixed for it by an intelligence outside of it : the organism develops and the principle of its development is within it.

Now, when we think of the universe, we may look upon it as a mere Aggregate, as a Mechanical Whole, or as an Organism. In the first case, the parts of which it consists are merely juxtaposed ; nothing is connected with any other thing. In the other two cases, the universe is viewed as a system, a whole in which parts are essentially

related to each other and to the whole. So regarded, the *universe* is *turned into one*. By this it is not implied that there is no difference between a grape and the planet Mars, that my knife and the currency notes in your pocket are the same. All that is implied is that a unity runs through all the diversity that we experience. Nature is one; a rosary and not a number of beads only.

From this conception of the Unity of Nature it should follow that a thorough knowledge of a part will enable us to know the whole. If we were to find some skulls of human beings that lived in the remote past, we should be able to construct mentally the entire bodies of these men. And seeing that in the Universe everything bears relation to everything else, a real acquaintance with a part of Nature should give us an insight into the nature of the whole reality. This thought has been finely expressed by Tennyson in the following lines:—

Flower in the crannied wall,
I pluck you out of the crannies,
I hold you here, root and all, in my hand,
Little flower—but if I could understand
What you are, root and all, and all in all,
I should know what God and man is,

2. Uniformity of Nature.

To many that are not in the habit of philosophically reflecting about things, this conception of the Unity of Nature would appear something astounding. And many who can reflect refuse to accept that a sufficiently strong case for the unity of all Nature is made out. What can I know of the formation of rocks in North America, if I thoroughly understand the structure of my own nervous system? Even if all the physical world were one system, we should still have an order of facts that will not fit in. How can my conscience or your talent cohere with things that can be weighed, divided and compounded? Science may postulate unity of Nature, but the evidence that is available simply warrants the assumption of a certain regularity or orderliness. This regularity or orderliness is known as the Uniformity of nature. We shall be nearer facts, it would appear, if we speak of the Uniformity of nature rather than of the Unity of Nature. We may go further and say that this orderliness also is not of one uniform type but is of various forms. If this be so, we should speak of the *Uniformities* in Nature. 'The course of the world,' says Bain, 'is not *a Uniformity*, but *Uniformities*. There are departments of uniformity which are

radically distinct.' Each of these departments has its own laws.

3. Uniformities of Nature.

We may now indicate the various forms in which the general orderliness of the Universe manifests itself—

(i) *Uniformities of Succession.*

Inductive sciences are concerned with one particular form of succession, namely, Causation. The Uniformity of Causation states that if a cause once produces a particular effect, in identical circumstances it will always produce the same effect. Events follow one another, not capriciously but in regular order. What is once true, is always true. This implies that effects do need causes, that no change can occur without a cause. This implication is the Law of Universal Causation. Strictly speaking, these two principles are quite distinct ; the principle of causation states that no change arises out of mere vacuity or stillness ; the principle of Uniformity states that in every change the connection between antecedents and consequents is uniform. It is conceivable that in a world every change should need a cause but the connection should not be uniform. In such a world whenever a man is hungry, he must do *something* to appease his

hunger. But one day he may have to eat something, on another to play on the violin, and on another day still to gaze at the stars. On the other hand, eating something might on one occasion appease hunger, on another develop a taste for music, and on another still make him invisible. Using symbols, we may say that in such a world, x may be produced by A *or* B *or* C, and A may produce x *or* y *or* z. Experience of the past would furnish no guidance for the future. This means that though we believed in the Law of Causation, we could not generalize. Even causal connections subsisting at any particular moment could not be discovered. For where anything could produce anything, there would be nothing to show which of the numerous antecedents of an event was responsible for producing it. It is the invariableness of sequence that enables us to find a causal connection between two phenomena. For this reason, some logicians have maintained that to assert causation is to assert uniformity of causation. However, all that the above argument proves is that in the absence of Uniformity, there would be no means of *detecting* causation and there would be no ground for *generalisation*. The argument does not disprove the *existence* of the causal connection. In a world where there are causal connections with-

out uniformity, there would be no order, and for us (if we could exist in it) changes would be happening, as if they were uncaused. This, however, is not the same thing as saying that they would be actually uncaused.

In the world in which we live, we expect that all changes will be caused and that the causal connection will be uniform. It is fortunate that the world satisfies both these demands of our nature, and yet is it not strange that it should do so?

(ii) *Uniformities of Co-existence.*

Venn states the Uniformity of Co-existence as follows:—

'If all the co-existent elements, *except one*,—*viz.*, the one which occupies the place corresponding to that of effect,—be repeated, then this one also will necessarily be secured.'

In our daily life we often act on this assumption. A particular colour and form of a fruit are accepted as a ground of inference about its taste. Of course, sometimes we are sadly disappointed, but that does not shake our belief in the Uniformity. We think rather that all the concomitants of the desired taste were either not known or not observed ; just as when the anticipated effect does not follow, we believe that some antecedents have remained undetected.

The following kinds of co-existence may be noted :—

(a) Natural substances furnish good examples of co-existence inasmuch as they have a number of co-existent attributes. Every piece of gold has a number of attributes—

It is 19·3 times as heavy as water ; it can crystallise ; it is tenacious ; it melts at 1,200°C ; it is a conductor of electricity ; its atom is 196 times as heavy as that of Hydrogen ; it is dissolved in *aqua regia* (a mixture of nitric and hydrochloric acids), though neither of the two acids will individually dissolve it.

'The diamond has always a characteristic colour, brightness and form ; is always combustible, and, when burnt, produces carbonic acid gas ; cannot be cut by other substances ; and so forth.' (Mellone.)

The most notable example of this type of uniformity is the co-existence of *inertia* and *gravity* in every piece of matter.

(b) What are called Natural kinds by Mill furnish another good class of co-existences. In the animal and vegetable kingdom, we find a number of representatives of every species and these resemble one another in possessing some common attributes. Every crow and every orange is the subject of a number of coinhering attributes.

Mammals of a certain order are all ruminant and many ruminants are cloven-footed.

These are the two most important forms of Uniformity. Inductive sciences are concerned with Uniformity of Causation and often the phrase Uniformity of Nature (even Unity of Nature) means no more than Uniformity of Causation. We have seen, however, that we do sometimes base our inferences on Uniformity of Co-existence. How are these two Uniformities related to each other? According to Mill, 'they stand upon a totally different footing. The Uniformities of succession are based on the Law of causation, but there is no general axiom, standing in the same relation to the Uniformities of Co-existence as the law of causation does to those of succession.' In Mill's opinion, nature 'did not make the warp and the woof in the texture of the phenomenal world of equal strength. Longitudinally, or down the stream of time, the fibres are long and tough, but laterally they are few and feeble. In the one direction the web will bear a heavy strain, whilst in the other we can place but feeble trust in it.'* Professor Minto, on the other hand, thinks that the distinction is immaterial to Logic. 'What Logic is concerned

* Venn : Empirical Logic, 75.

with is the observation of facts and the validity of any inference based on them ; and in these respects it makes no difference whether the Uniformity that we observe and found upon is one of sequence or of co-existence.' According to Minto, the major of the Inductive syllogism is the principle that *observed Uniformities of Nature continue.* 'If we do not believe in the continuance of the observed uniformities, why do we turn our eyes to the window expecting to find it in its accustomed order of place? Why do we not look for it in another wall? Why do we dip our pens in ink, and expect the application of them to white paper to be followed by a black mark ?'*

(*iii*) *Uniformities of Persistence.*

These may be regarded as a distinct class. When I go to the college, locking my door, I expect that on my return I shall find the furniture as I leave it. If I find that the stool is on the chair, I am shocked. The shock of surprise is due to the assumption that things will continue in their respective positions. This may be brought under the law of Causation and Uniformity of Causation. I reason thus—The change in the position of the stool requires a cause to explain it none of the causes known to be working in

* Logic : 278, 279.

this room, will, by working in their usual manner, produce such a result. Again we believe that the sun will rise to-morrow. Why do we believe it? Simply because we assume that the present course of nature will persist. And how can we be absolutely sure that it will? The sun has been rising daily in the past and this constitutes a strong presumption that it will rise to-morrow. This, however, does not entitle us to maintain that it must rise to-morrow. Suppose that it does not rise to-morrow. The Uniformity of Causation will remain unaffected. This principle states that *if* the conditions are repeated, the consequence will follow as before. It does not guarantee that the conditions *will* be repeated. Nature may not repeat itself. Some logicians (*e.g.*, Jevons) say that the Uniformity of Nature is liable to exceptions. The only element of truth in this is that, for all we know, the present order of Nature may not persist.

Besides these uniformities, Venn mentions the uniformities of rhythmic character and the Uniformities of probability. The cycles of day and night and summer and winter are familiar instances of the first. When we sow the seed, we expect that it will grow and ripen. This, however, is only a case of our belief in the continuance of the present order of Nature. The Uni-

formity of Probability combines individual irregularity with the average regularity. In a city, for instance, ten men in a million commit suicide every year. This furnishes no ground to infer that a particular individual will commit suicide, but we may depend upon it that ten men or about as many will put an end to their life. We should note, however, that the average also is liable to change.

4. The ground of belief in Uniformity.

We have seen that we cannot generalise unless we believe that the course of Nature is uniform. Now how do we come to have such a belief? And why should we suppose that this belief is rational? These two questions are quite distinct; one concerns the *origin* of the belief, the other concerns the *validity* of the belief.

Strictly speaking, the first question is psychological and its discussion should be relegated to Psychology. The second question about the *evidence* on which the belief rests is logical. Both these questions, however, are intimately connected and are generally discussed together.

The followers of the *Intuitionalist School* maintain that the belief in Universal Causation and the Uniformity of Nature is intuitive. Every man is born with it. We do not *learn*

that changes are caused and their causation is uniform; we only *discover* the presence of these beliefs in our minds. Our minds are so constituted that we cannot help believing in them.

The *Empiricists* reject this explanation. They maintain that like all other beliefs these also are grounded upon experience. We observe that every change is preceded by an antecedent and that the sequence is uniform. As our experience widens, the belief gains in strength, for nothing contradicts it. Testimony of our contemporaries and of those that have gone before us furnishes additional confirmation. Hume and Mill are representatives of this view. 'I must protest,' says Mill, 'against adducing as evidence of the truth of a fact in external nature, the disposition, however strong, or however general, of the human mind to believe it. Belief is not proof and does not dispense with necessity of proof.' As to the proof of the Law of Causation, he says that 'we arrive at this universal law by generalisation from many laws of inferior generality. We should never have had the notion of causation as a condition of all phenomena, unless many cases of causation, or, in other words, many partial uniformities of sequence had previously become familiar.' Mill thus bases our belief in these Laws on uncontradicted experience.

Mansel holds that the idea of Universal causation is intuitive, but the belief in Uniformity is derived from experience. That is, the constitution of the human mind is such as to demand that every change is caused, that no phenomenon can arise out of vacuity and stillness ; but we have to open our eyes and observe before we can know that the course of Nature is uniform.

The *Evolutional view* is a compromise between the Intuitive and the Empirical view. According to this view, experience should mean not the individual's experience, but the experience of the race. Each generation transmits to its successor its experience or a disposition to have certain experiences. The individual, as he is now, does not *learn* about these laws, but his remote ancestors had to derive their belief from experience.

We cannot enter here into a detailed discussion of these views. Against the intuitional view it may be remarked that though the belief in Causation seems to be universal, the belief in the Uniformity of Causation is far from being universal. Not to talk of the vulgar masses, even fairly educated men are found to believe in the suspension or violation of Natural Law. Against Mill, the following points may be urged:—

(1) As Mill himself admits, every person's consciousness assures him that he does not always

expect uniformity in the course of events ; he does not always believe that the unknown will be similar to the known, that the future will resemble the past. ' The course of nature, in truth, is not only uniform, it is also infinitely various. Some phenomena are always seen to secur in the very same combinations in which we met with them at first ; others seem altogether capricious ; while some, which we had been accustomed to regard as bound down exclusively to a particular set of combinations, we unexpectedly find detached from some of the elements with which we had hitherto found them conjoined, and united to others of quite a contrary description.' If in these last cases we believe that some causes that remain unnoter are also operating or counteracting the known causes, it is because we suppose that the course of Nature is uniform. Observation in the sense of mere sensuous experience is both uniform and multiform, and cannot be the ground of the belief in Uniformity.

(2) The foundations on which these foundations of all Inference are based by Mill are very weak. He bases them on simple Enumeration. This form of Induction, as we shall see in the sequel, is of very little value. It should be noted that of all the facts of causation that can possibly be observed, only a few are actually observed.

And even if all that has been, had been observed, that should not furnish adequate ground for generealising about the future. It is true that as our experience widens, our belief in these laws becomes stronger, but the strength of a belief, as Mill himself insists, is no ground for accepting it as rational. Mill and his followers do not speak of *universal* causation, but of causation co-existent with the sum-total of human experience. Obviously, this experience can be only of the past and the present.

(3) Mill and his followers speak of causation and uniformity of causation as certain. However, all that can be reasonably affirmed on empirical grounds is that they possess a high degree of probability, and may have to be rejected in the light of future experience. Consistent empiricism should not go beyond this. This position is frankly accepted by some empiricists. 'We have no warrant,' says Yerkes, 'for our expectation of uniformity other than our previous experience. What we have not seen happen, we do not expect to witness. The causal relation is a great generalisation. From the observations, millions of times repeated, that one event precedes another, we have drawn the conclusion that things must happen thus. This conclusion is valid and serviceable, so long as it is supported by observa-

tion; but just so soon as it is contradicted we should revise it. It is rather unfortunate that we should feel towards this particular generalisation a sort of reverence. We treat it as though it were Heaven-born, sacred. As a matter of fact, it probably has no greater claim than have many other generalisations. All are human-made and should be held subject to modification.' *

Where then lies the truth? From their very infancy men *act* on Universal Causation and Uniformity. Even most animals act *as if* they believed in universal order. We cannot say, however, that the animal or the infant *believes* in Uniformity. The principle is implicit in their lives, but they are not conscious of its presence and operation. The human being, long before he becomes a logical thinker, becomes aware of the presence of order. It is, however, over small areas that he recognises the reign of Law. With the extension of experience the belief widens in scope, till in the end all nature is conceived to be under the reign of Law. Experience does not generate the belief ; it only makes it explicit and confirms it.

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* Introduction to Psychology : 314-5.

CHAPTER VII

PLURALITY OF CAUSES AND INTER-MIXTURE OF EFFECTS

I. Obstacles to Explanation.

The fundamental business of Induction is to discover causal laws on the basis of observed causal connections. Popularly considered, causal connections are simple enough—one phenomenon is indispensable to the occurrence of another. We have to distinguish among a mass of co-existent phenomena the particular effect due to a given cause, or the particular cause which gave birth to a given effect. We may assume that every effect is connected exclusively with a single cause and secondly that it is incapable of being mixed and confounded with any other co-existent effect. 'If such were the fact' says Mill, 'it would be comparatively an easy task to investigate the laws of Nature. But the supposition does not hold in either of its parts. In the first place, it is not true that the same phenomenon is always produced by the same cause; the effect *a* may sometimes arise from A; sometimes from B. And, secondly, the effects of different

causes are often not dissimilar, but homogeneous, and marked out by no assignable boundaries from one another; A and B may produce not *a* and *b*, but different portions of an effect *a*. The obscurity and difficulty of the investigation of the laws of phenomena is singularly increased by the necessity of adverting to these two circumstances—Intermixture of Effects and Plurality of Causes.'*

We shall briefly examine both these difficulties.

2. Plurality of Causes.

We should distinguish between the complexity of a cause and Plurality of Causes. When we say that a cause is complex, we mean that a number of conditions (or partial causes) co-operate to produce a certain effect. By Plurality of Causes we mean that each one of a number of causes is competent to produce the effect. My present health is due to exercise, to nutricious food, to regular habits, to congenial work—all these taken together constitute the cause. This is an instance of a complex cause. On the other hand, a man's death may be due to drowning, over-eating, typhoid fever or starvation. Each of these taken singly is sufficient to produce the

* Logic III, X., 1.

effect. A student may pass the examination *either* because he has worked hard, *or* because he is exceptionally intelligent, *or* because there has been leakage of the examination papers, *or* because he has been unscrupulous and the superintendent of the examination shortsighted. These are cases of Plurality of Causes.

There is no doubt that the doctrine of Plurality of Causes is consistent with the popular view of causation. Ordinarily, we do think that the same effect may be due now to one and again to another circumstance. But is it consistent with the scientific view of Causation? Mill accepts this doctrine, but a moment's thought will convince us that it is inconsistent with his account of causation. The essential features of a cause, according to Mill, are that it is *invariable* and *unconditional* antecedent of the effect. How can A be the *invariable* antecedent of *a*, if even B or C can produce *a*? Though Mill constantly speaks of the cause as the invariable antecedent of a phenomenon, yet he really thinks of the effect and means to define it as the invariable consequent of a cause. The causal relation according to Mill is invariable only in one direction. Given the cause, the effect invariably follows, but we cannot say that a certain effect is produced always by the same cause.

The doctrine of Plurality of Causes can be accepted only so long as we do not note the complexity of an effect and feel the need of analysing it. In popular thought, one aspect of the total effect is singled out and taken for the whole. This aspect happens to be most conspicuous from the standpoint of our present purpose, and, in consequence, other aspects are ignored and treated as non-existent. Take the case of a man's death. Mill says that there are many causes of death. But is the effect really the same whether the cause was starvation, over-eating or typhoid fever? Certainly not ; only one aspect, the complete cessation of consciousness, is seized and spoken of as the whole effect. Other aspects may sometimes become more important and when we are in search of the cause of death *in a particular case*, we direct our attention to these other aspects of the total result. We go beyond the cessation of consciousness and enquire what *kind* of death this particular death has been. 'A man's body is found dead in water. It may be a question whether death came by drowning or by previous violence. He may have been suffocated and afterwards thrown into the water. But the circumstances will tell the true story. Death by drowning has distinctive symptoms. If drowning was the cause, water will be found in the stomach and

froth in the trachea.'* 'Different causes have distinctive ways of operating, and leave behind them marks of their presence by which their agency in a given case may be recognised.' Commenting on the same point, Mellone remarks :—" Life is a complex process consisting of a multitude of co-operating processes, of which some are directly essential. If any one of these essential processes is interfered with, life ceases ; and the interference can only be of one kind. Hence, there are many causes of death only because there are many kinds of death ; 'death' is a fact as complex as 'life.' "†

We have spoken of the success of candidates being due to hard work, exceptional intelligence, or use of unfair means. Strictly speaking, the result in all these cases is not the same. Popular thought singles out one aspect—the name appearing in the Gazette and a certificate granted, and for popular thought this is enough.

However, if we aim at clear thinking, we must recognise the *reciprocal* character of the causal relation. The sequence is invariable in both directions. If A is the cause of *a*, then we may say not only that wherever A operates, *a*

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* Minto : Logic, 342.

† Logic, 277.

will be found, but also that wherever *a* is found, A must have operated. The Law of Causation is to be expressed by two hypothetical propositions—(1) if A, then *a*, and (2) if *a*, then A. The second proposition can also be expressed as—if not A, then not *a*. The cause is the circumstance in whose presence the event always happens and in whose absence the event never happens.

To sum up: We have found that

(1) The doctrine of Plurality of Causes is valid so long as we think of the causal relation in a popular way.

(2) The doctrine is inconsistent with Mill's account of the causal relation.

(3) The doctrine is inconsistent with the scientific view of the causal relation. Scientifically considered, the causal relation is reciprocal.

(4) The mistake of supposing that the same effect may be due to a number of causes taken severally arises from an imperfect analysis of the effect, *i.e.*, from accepting one aspect of the effect as the total effect.

3. Intermixture of Effects.

Sometimes, a number of causes work simultaneously and the effect that each one of them produces is separately observable. Five or six men contribute articles to a magazine and each con-

tribution bears upon it some distinctive marks whereby it indicates its authorship. Even if the articles are not stated to be the contributions of different individuals, even if they continue each other, as do the paragraphs of a single article, they can be distinguished one from the other. Again, when I write these words on the sheet of paper before me, I feel my contact with the chair, hear the noise being made in the street, and taste the piece of sugar in my mouth. The piece of sugar, the vehicles and the chair are simultaneously working to produce a change in my consciousness; but it is possible to disengage in my consciousness the separate effects of these causes. The noise of the vehicles does not blend with the taste of sugar in such a way as to baffle discrimination. It may happen, however, that the causes interfere with one another. In such a case the effects will not remain distinct. They will mix with one another. Such cases are spoken of as cases of Composition of Causes or Intermixture of Effects. The problem in such cases is to assign to each cause the effect for which it is responsible. The Intermixture of Effects may assume two forms—the total effect may be of the *same kind* as the component effects, or it may be *qualitatively different* from them. In the first case, the Intermixture is known as Homogeneous; in the

latter, Heterogeneous or Heteropathic. Some instances of the Homogeneous Intermixture are the following :—(1) Each student in the class makes noise ; the resultant noise is the sum of the noises that are made. (2) I can lift two maunds ; my brother can lift three maunds ; when we work together, we can lift five maunds. (3) Two pairs of rowers are rowing a boat. With what velocity and in what direction will the boat move? This depends upon the forces being employed by the rowers and the direction thereof, on the speed of the stream and on the resistance that may be offered by the air. The resultant motion can be accurately determined if we know the component causes. (4) The present awakening in the country is due to the co-operation of several causes—the work of the reformers, contact with a highly enlightened nation of the West, intelligent interest in India's past and several others. (5) A man's character is the resultant of various forces acting simultaneously. A part is derived from his parents, and through them from his ancestors ; a part is due to the influence of his surroundings, and for a part he has to thank his own spiritual struggles.

The task of assigning to each of these causes the portion in the total effect for which that cause is responsible is often very difficult. Sometimes

the forces may neutralise each other and there may be no apparent effect. I may be pushing the table in one direction and you may be pushing it in the opposite direction. We may both exhaust ourselves and yet the table may not change its position. In such cases it would be wrong to say that the causes have no effect ; each cause produces an effect ; only the sum-total of the effects is zero.

In the Heterogeneous Intermixture, the resultant effect is not the sum of the effects that the causes would severally produce. It is qualitatively different from them. Chemical composition of simple substances furnishes a good example of such intermixture. Hydrogen and Oxygen, when they combine in certain proportions, produce water. Hydrogen burns and Oxygen is a necessary medium for things to burn in ; but water neither burns itself nor allows other things to burn in it. It quenches thirst and wets, which neither of its constituents can do. In cases of such intermixture, a knowledge of the effects of the component causes taken severally does not enable us to calculate the total effect when the causes work together. We have to appeal to experience to know how water behaves ; we cannot deduce its properties from the properties of Hydrogen and Oxygen.

CHAPTER VIII

IMPERFECT INDUCTIONS

A. ENUMERATIVE INDUCTION

1. Ground of Enumerative Induction.

In Enumerative Induction or Induction by Simple Enumeration, the sole ground of Induction is said to be our previous experience. Simple Enumeration is *mere* enumeration. We affirm that a certain relation holds in all cases, because the cases that have been noted by us all exhibit that relation. Our belief in the universality of the relation becomes stronger as the number of instances observed increases. The question that we have to discuss here is this—does the *number* of instances, as such, possess any *scientific* value? Some logicians answer this emphatically in the negative. 'No mere counting of instances, however many they may be, can make a conclusion more certain. We may know that S and P are conjoined twice or two thousand or two million times ; but this does not warrant us in saying that they are *always conjoined*, unless we have something more than the mere number to go upon. A mere *enumeratio simplex*, a mere assemblage

of positive instances, is simply worthless.'* If all the triangles that we have examined show that two sides are greater than the third, we have not *proved* that in all triangles this must be so. At most, we can say that something has been found true so far as we have observed. A single *negative* instance may refute our conclusion.

This criticism seems to be very damaging, but as a matter of fact we do place reliance on such arguments. Is it all irrational? No ; even those who denounce Enumerative Induction as a *demonstration*, accept the position that the argument may acquire some force, *if we are sure that exceptions, if there were any, would have come under our notice*. Every instance has some uniqueness or individuality, and if all the instances agree in showing a connection, the presumption that the connection is universal is not quite misplaced. 'Some reason must exist,' says Joseph, 'why all these instances exhibit the same property. If it is not in virtue of their common character X, it must be in virtue of some other common feature. When the variety of circumstances is great, under which the instances are found, and the differences many which they present along with their identity as X, it is harder to find any other common

* Mellone : Logic, 249.

features than what are included in classing them as X . . . All men are mortal ; for if men need not die except through the accident of circumstances that are not involved in being man, is it not strange that no man has avoided falling in with these circumstances? There is force in the question. The number and variety of our observations on the point are such that almost everything can be eliminated ; almost everything that has befallen a man, except what is involved in being man, has also not befallen other men ; who therefore ought not to have died, if it were because of it that men die. Something involved in being man must therefore surely be the cause of dying.

Induction by simple enumeration rests then on an implied elimination, but the elimination is half-unconscious, and mostly incomplete ; and therefore the exclusion is of very problematic value.'*

2. Value of an Enumerative Induction.

The ground of Enumerative Induction is not *mere* enumeration. It is implied, half-unconscious, elimination. If the instances examined are not all of the same type, the argument has

* Joseph : Logic, 491.

some force, though it falls far short of complete demonstration. Even when it works most satisfactorily, it cannot establish a *Law of Nature;* at best it can give us an *Empirical Generalisation.* It can tell us that a certain connection *is* there, but it cannot say *why* it exists. By the help of Enumerative Induction, we could know that, in all triangles, the two sides *are* greater than the third. A geometrician cannot hope to measure *all* triangles and even if he could measure them, he would prefer to *prove* that this relation *must* subsist. For this, he need examine only a single triangle. It must also be noted that a single exception may require a modification of the generalisation that is the result of a very large number of observations.

3. Results of Enumeration.

If the generalisation only covers the cases that have been examined, the result is a Perfect Induction. Here the conclusion is not problematic, because there is no conclusion worth the name. If the generalisation goes beyond actual experience, but that experience, so far as it goes, exhibits a uniform relation, the result is an Empirical Law. Sometimes we find that our experience, so far as it goes, is not uniform. In some cases we find the connection, whereas in others

we do not find it. Here, our object is to determine the amount of likelihood of the presence of the connection in a new case. If of all the students in a college that I have come across, 70 per cent. are intelligent and 30 per cent. unintelligent, I conclude about a new student that the likelihood of his being intelligent rather than unintelligent is 70 per cent. If in my morning walks, I meet A every other day, and B once in five days, I may expect to meet them both together once in ten days. This form of Enumeration is the basis of the Theory of Probability.

B. ANALOGY

4. Character of the Argument.

Analogy originally meant the sameness of relation. An argument from Analogy meant an inference from a resemblance of the relation in which two terms stand to two other terms. If the relation is quantitative, the argument becomes mathematical in character and is known as Proportion. If *a* is to *b* as *c* is to *d*, and we know that *a* is double of *b*, we can say that *c* is double of *d*. In modern Logic, Analogy is understood to mean any resemblance between two things and not merely a resemblance of relations in which they respectively stand to two other things.

Argument from Analogy now means an argument from some degree of resemblance to a further resemblance. A and B resemble each other in the possession of certain attributes R', R'', R'''. A is known to possess an additional property P ; and we want to know whether this property P will be found in B also. This states the problem in its simplest form.

We have mentioned only the points of resemblance. Such points are always accompanied by points of difference. Resemblance is only a partial identity. Before we can infer about the presence of P in B, we must note in what respects A and B differ. Some attributes will be found in A which are not found in B, and, on the other hand, B will possess some marks that are not to be found in A. Let these attributes be denoted by d', d'', d''', and $d_{\prime}$, $d_{\prime\prime}$, $d_{\prime\prime\prime}$ respectively. We find then that A has $R', R'', R''', \ldots d', d'', d''' \ldots P$; and B has $R', R'', R''' \ldots d_{\prime}, d_{\prime\prime}, d_{\prime\prime\prime} \ldots$

Our problem is to find whether P will be found in B. Will it be one of the points of resemblance, like R', R'', or one of the points of difference, like d', d''?

5. Ground of the Argument from Analogy.

How shall we proceed to find this? According to Mill, we should ascertain the extent of the

resemblance and compare it first with the amount of ascertained difference and next with the extent of the unexplored region of unascertained properties. Where the resemblance is very great, the ascertained difference is very small, and our knowledge of the subject-matter tolerably extensive, the argument from Analogy may approach in strength very near to a valid induction. If, after much observation of B, we find that it agrees with A in nine out of ten of its known properties, we may conclude with a probability of nine to one, that it will possess any given derivative property of A.'*

Mill's view is open to the following objections :—

(i) The points of resemblance and difference cannot be counted as coins or cards can be counted. They are not individuals that have each a separate existence. It is often extremely difficult to say whether a point is one property or more. You recognise that you resemble your brother to some extent. Can you analyse this resemblance and put it down as so many distinct points? Is love of culture one point? Is aesthetic taste one point? You will realise the difficulty,

* Logic : III. XX. 3.

if you actually begin to compare any two familiar things.

(*ii*) Mill seems to think that the ground of inference here is the *amount of similarity*, whereas, as Welton points out, in reality the force of the argument depends upon the *character of the identity*. All points R′, R″, d′, d″, &c., are not of equal significance. If they were, a simple numerical comparison would help us in our investigation. As it is, some points are essential and others are inessential. If the resemblance is essential and the difference is inessential, the probability that the point in question will be found in both the things is considerable. We should see whether the points of resemblance or those of difference are the more material points.

How can we know whether a point is or is not material? Obviously, by referring to the purpose of the enquiry. The manager of a theatre who has been able to attract you to his performances, and wants to know whether he will succeed in attracting me also, will try to see whether I have your tastes and your means. That we are both 5 feet 9 inches high, are married in the same village and have both a living uncle, is very probably irrelevant, so far as he is concerned.

6. Cautions to be observed.

Fowler lays down the following cautions to be observed before we draw an inference from analogy :

(*i*) 'We must have no evidence that there is any causal connection between the new property and any of the known points of resemblance or difference.'

The moon resembles the earth in being a large spheroid revolving round another body and in several other particulars. We may argue that it probably resembles the earth in sustaining vegetable and animal life. We know, however, that animal and vegetable life, as we know it on our earth, cannot exist without moisture, and, so far as we are able to ascertain, there is no mositure on the moon. This one point, because it is causally connected with the phenomenon in question (existence of plant and animal life on the moon), should settle the matter. If I love to see pantomimes and want to know whether you would be willing to accompany me to see one this evening, it is no use noting the many points of resemblance between us, if you are blind. This one fact settles the question. In these cases the argument is not analogical, and if analogy is employed, it will be misleading.

(*ii*) 'Though there must be no evidence to connect the property in question with any of the known points of resemblance or difference, there must, on the other hand, be no evidence to disconnect it.'

This means that if any points are definitely known to be irrelevant, they must be left out of consideration. The reason is obvious. We count these points of resemblance and difference, because we assume that there is a chance of their being connected with the property under consideration and their presence in the thing may be taken to be a ground for inferring that this property also is present.

(*iii*) 'We must have no reason to suspect that any of the known points of resemblance or difference, of which the argument takes account, are causally connected with one another.'

If any two of the properties are joint effects of the same cause or are related to each other as cause and effect, they should count as one point only. The object of counting points of resemblance and difference is to see whether the two things mainly agree or differ. If all the points that we consider are not independent, we swell the list of points on one or the other side without justification and vitiate the argument.

(*iv*) 'It is only when we have reason to

suppose that we are acquainted with a considerable proportion of the properties of two objects, that the argument from analogy can have much weight.'

As Mill insists, we should possess a tolerably extensive knowledge of the subject-matter.

7. Analogy and Enumerative Induction.

In Simple Enumeration we argue from a number of instances ; in Analogy from a number of points of resemblance. Analogy goes beyond Simple Enumeration inasmuch as it analyses the two things that it compares; whereas Simple Enumeration is unanalytical. Inductive science is essentially analytic in method. Analogy, therefore, approaches scientific method nearer than Simple Enumeration does. Simple Enumeration and Analogy are both Imperfect Inductions, because they cannot prove the existence of a causal connection. They only *suggest* the existence of such a connection. They suggest an hypothesis which has to be established by Scientific Induction. They have both some value in the Logic of Discovery, but none in the Logic of Evidence.

8. Homology.

In Biology, Analogy is understood to mean superficial similarity. The bat and the butterfly resemble in having wings, but they differ in essen-

tial features of their structure. While discussing the subject of classification, we found that a natural classification enables us to infer of any other member of a class a great part of what we know about any particular member. Animals or plants are brought together to form one class on the basis of similarity of plan or structure. This deeper similarity is known as Homology. Homology and not Analogy is the basis of classification. In the general outline of the body a whale resembles a fish. Both live in water, and the hinder limbs in both work like paddles. However, these resemblances in external form and function do not make the whale a fish. The structure of the whale is different from that of the fish. The whale is a mammal ; in its early life it has teeth ; it has hair on the skin ; it has lungs. When we want to infer something about the whale, the inference should be based upon these characteristics rather than upon superficial appearance. In the language of Biology, we should draw an inference from Homology and not from Analogy.

9. Examples of Analogy.

Argument from Analogy is not conclusive, but we often employ it, and have to employ it, for want of a better method.

Probably you believe in the existence of minds other than your own. Is this belief rational? You cannot doubt the existence of your own mind. If you doubted it, the doubt itself would be a proof that your mind exists. Doubt itself is a state of consciousness. Whatever else you may doubt, you cannot doubt that your consciousness exists. But the same thing cannot be said with reference to other minds. You do not know other minds directly and immediately, as you know your own mind. And I who am writing these lines and using the pronoun 'you,' assume that I am not the only mind on this earth. My belief in the existence of minds other than my own is very strong—almost as strong as in my own existence. I *know directly* that I am; I *infer* that you are. And you too, if you are, *know directly* that you are, and *infer* that I am. This inference about the existence of other minds is, according to one explanation, Analogical Inference. I find that my physical frame is connected with a mind : I find that my mind expresses itself in certain movements. I perceive other bodies resembling my body and see that movements similar to my movements are performed by them. I *infer* that in those cases also there are minds that express themselves in movements.

An individual resembles a society in some

respects. Both are complex wholes of interdependent parts; both evolve according to the same principles. The individual grows to maturity and then decays and dies. Is this also the fate of societies? No old individual can become young again. He must die. If the same were true of societies, the societies that are at the zenith of their glory to-day must inevitably decline; and for an aged society, like the Chinese or our own, there should be little hope. But can we attach any meaning to the words 'old age of society?' 'Bodies politic die,' says Mill, 'but it is of disease or violent death; they have no old age.'

CHAPTER IX

METHODS OF SCIENTIFIC INDUCTION

1. General Character of the Methods.

The ultimate goal of science is explanation of facts. Inductive sciences have to determine causes of given effects and to discover the laws according to which these causes operate. As we have seen in a previous chapter, the same phenomenon may appear both as cause and effect. It is a link in a causal chain ; it is a cause with reference to what follows it and an effect with reference to what precedes it. Simple Enumeration and Analogy cannot establish a causal connection. They can only suggest the existence of such a connection. To see what this suggestion is worth is the business of Scientific Induction. Induction employs some devices which are known as the Inductive Methods. They are five in number. Some are used to discover causes of effects, while others to discover effects of causes. Again, some are used just to establish the causal connection between phenomena, while others seek to determine the causal relation in its quantitative aspect. That is, their aim is not only to

show that A is the cause of x, but also to determine how much of A is required to produce a certain amount of x. For purposes of convenience, we treat of these methods as if they were quite independent of one another. In actual investigation, they often co-operate as stages in one and the same process. From one point of view, we may call them all varieties of the same Method. They are all different forms of the Method of Elimination. As we said in a previous chapter, causes and effects do not appear in isolation : almost always they are found embedded in irrelevant circumstances. The business of Scientific Induction is to analyse the complex situation and disengage the relevant elements from the irrelevant ones. What is indispensable to the production of an effect is its cause. This means that when the cause is present, the effect must be present, and when the cause is absent the effect must be absent. These two grounds of Elimination may be stated thus :—

1. Nothing is the cause of a phenomenon in the absence of which the phenomenon nevertheless occurs.

2. Nothing is the cause of a phenomenon in the presence of which the phenomenon nevertheless fails to occur.

After these preliminary remarks about their

general character, we may now proceed to give a short account of each of these Methods.

1. THE METHOD OF AGREEMENT

2. Principle of the Method.

Mill states the canon of this Method as follows :—

If two or more instances of the phenomenon under investigation have only one circumstance in common, the circumstance in which alone all the instances agree is the cause (or effect) of the given phenomenon.

This can be symbolically represented thus :

The circumstances	A, B, C	produce	x, y, z.
,,	A, D, E	,,	x, r, s.
,,	A, G, H	,,	x, p, q.
	&c.,		&c.

We can infer that A is the cause of x.

This notation suggests that there are a number of distinct cause-elements and a number of distinct effect-elements, each element in the latter series corresponding to an element in the former series, and all that we have to do is to relate these distinct elements of the two series to each other. As a matter of fact, the division of the cause and the effect is not so definite and it is not possible to secure the condition that one ele-

ment in one series shall correspond to one element in the other series. It would be better if all the elements, excepting the constant ones, were put together and denoted by a single letter. This would give the following resolution :—

A+B	produce	x+y
A+C	,,	x+r
A+D	,,	x+z

The essential point is that in a number of instances, where everything else changes, the phenomenon in question (x) and a certain circumstance (A) remain constantly present. This circumstance is the cause of the phenomenon.

3. Examples of the Method of agreement.

Instances of the application of this method should readily occur to the reader. A man suffers from headache and is anxious to know its cause. What can he do? The antecedents of this phenomenon are many circumstances in which the cause lies embedded. He got a new magazine yesterday, wrote a letter to his uncle, had his first lesson in instrumental music, and kept late hours. The cause must be one of these, supposing these to be all the circumstances that are relevant to the present case ; but which one

of these is it? The man remembers that he has had headache before too. What were the antecedent circumstances then? Suppose he finds that the receipt of a magazine was not a constant factor, nor the writing of a letter to his uncle. But whenever he had headache, he had passed a sleepless night. He naturally ascribes the headache to this. This is the circumstance in which all the cases of his having a headache agree. If some other persons also report that headache in their case is preceded by a sleepless night, his conviction that here he finds a causal connection becomes stronger.

How do we know that quinine cures malaria? We take a number of cases in which malaria has been cured and find that whatever other circumstances might or might not be present, the use of quinine was always there. It is in the presence of this circumstance that all the cases agree. This agreement is the basis of our inference.

4. Criticism of the Method.

This method is very commonly employed, but we must remember that its value as a scientific method is very small. It is not a final method. It serves as suggestive of experiments that can be performed according to another method. It is

the first step in Scientific Induction. Taken by itself it is open to the following criticism:—

(1) As is implied in the canon, as given by Mill, the method of agreement does not tell us anything about the nature of the causal connection that it seeks to establish. If A and x are constantly present together, we do not know whether A is the cause or the effect of x. In our own explanation, we have assumed that A occurs among the antecedents and x among the consequents, but this also is not clear in many cases. All that we know is that in a number of cases where all else changes, two elements remain constantly together. Even where we know that A is among the antecedents and x among the consequents, A may be only an indispensable part of the cause. Its presence may be necessary, but it may not be by itself sufficient to produce the effect. The application of a lighted match may be present in all cases of lighting fire, and yet this alone may not be enough to produce the result. Again, A and x may both be co-effects of the same cause; only, A occurs earlier than x. Both sleeplessness and headache may have been produced by overwork or worry.

(2) This method cannot tell us definitely that A and x are causally connected. They may be mere concomitants. 'Where there is sea,

there we find sky.' And yet the presence of the sea is not the cause of the presence of the sky. Animals that chew their cud are also cloven-footed, and yet we do not take ruminancy to be the cause of cloven-footedness.

(3) The Method of Agreement is open to the objection that the same effect may be due to a number of causes taken severally. As we have seen in a previous chapter, strictly speaking, the causal relation is reciprocal. A certain cause produces a certain effect and nothing else, and that effect is produced in no other way. But at the popular plane of thought, we have to recognise the fact that the same effect may be produced in several ways. In such a case it is possible that the common element in the antecedents is altogether inoperative. Fever may be cured by the use of several drugs, each of them to be taken with water. This method would ascribe the cure to the use of water. From a strictly scientific point of view, the effect in all the cases is not the same ; but from the practical point of view, we are interested only in the lowering of temperature and consequent disappearance of restlessness, and these are the same in all cases.

This method is employed at the popular plane of thought, and the recognition of plurality of causes as a legitimate doctrine would appear

to condemn the method as of no value at all. This serious defect is remedied by selecting our instances with judicious care. If the instances are varied and many, the probability that the common circumstance is irrelevant becomes very small. The Method of Agreement differs from Simple Enumeration in laying stress on the *variety* of instances as well as on their *number*. Simple Enumeration attaches importance only to the number of instances ; the Method of Agreement also to the character of these instances. It secures a number of instances which resemble only in the presence of a single common circumstance. This at any rate is the ideal, whereas Simple Enumeration does not worry about this at all.

(4) We may also add that the conditions of the application of this method can seldom be completely satisfied. The Method is one of observation, and is employed where manipulation of phenomena is not in our power. Now nature does not present instances that agree in a single circumstance. This is no criticism of the theoretic value of the Method ; it simply affirms that the Method does not possess much value in actual scientific investigation.

The points that can be urged against the Method, and have been urged against it, are many, but there is no need of exaggerating its defects or

limitations. It is not altogether without value. In some enquiries we have to depend upon this alone ; experiment there is out of the question. In others, we have to start on our enquiry with this. Though not the final step in the investigation, it is the first essential step. It does go beyond Simple Enumeration and Analogy, and though we cannot by its means completely establish the hypothesis that they suggest, it strengthens the suggestion that a causal connection does exist. The real significance of the Method is that when two events are found together (simultaneously or in succession), it is probable that they are causally connected ; and if the number and variety of the instances is large, the probability also is great.

11. THE METHOD OF DOUBLE AGREEMENT.

5. Principle of the Method.

Mill states the canon of this Method thus:—

If two or more instances in which the phenomenon occurs have only one circumstance in common, while two or more instances in which it does not occur have nothing in common save

the absence of that circumstance: the circumstance in which alone the two sets of instances differ, is the effect or the cause, or an indispensable part of the cause of the phenomenon.

This Method has been called by Mill the Joint Method of Agreement and Difference. It is also called the Indirect Method of Difference. Its character is best indicated by calling it the Method of Double Agreement, for, as Mill himself points out, its use involves a double employment of the Method of Agreement. In the Method of Agreement, we have a set of instances which all agree in the co-presence of a circumstance and the phenomenon under consideration. In the Method of Double Agreement, this set of Positive Instances is supplemented by a set of Negative Instances which agree only in the co-absence of that circumstance and the phenomenon. The probability that the circumstance and the phenomenon are causally connected is considerably increased.

6. Applications of the Method.

If I find that whenever I suffer from headache, I have kept late hours, I have a natural inclination to connect the headache with keeping late hours. If in addition, I find that when-

ever there is no headache, I sleep at the proper time, the conviction that the two phenomena are causally connected is naturally strengthened. If the cure of malaria has been uniformly accompanied by the use of quinine, and where malaria has not been cured, quinine has not been used, the cases of the second class resembling those of the first class in all other respects, quinine is naturally taken to be the cause of the cure. If we find that wherever plague rages, rats are found in large numbers, and where it does not rage, the houses are comparatively free from rats, there is a strong presumption that rats are somehow connected with plague. 'If when I take a particular kind of food, I find that I invariably suffer from some particular form of illness, whereas, when I leave it off, I cease to suffer, I entertain a double assurance that the food is the cause of my illness. I have observed that a certain plant is invariably plentiful on a particular soil; with a wide experience I fail to find it growing on any other soil; I feel confirmed in my belief that there is in this particular soil some chemical constituent, or some peculiar combination of chemical constituents, which is highly favourable, if not essential, to the growth of the plant.' (Fowler.)

7. The Negative Instances.

Jevons gives the following representation of the Method:—

Antecedents	*Consequents*
A B C	a b c
A D E	a d e
A F G	a f g
A H K	a h k
....	....
P Q	p q
R S	r s
T V	t v
X V	x v

(Elementary Lessons, 247.)

This representation is quite misleading. As Venn points out, 'the members of the second set of instances have a great deal more in common than the mere absence of A. For B, C, D, ... are also absent from them all ; in fact, the whole second set of instances agrees in displaying throughout the entire absence of every element in the first.'

Venn gives the antecedents thus:—

Affirmative	*Negative*
A B C D E	B C F G
A D E F G	D E H I
A F G H I	F G J K
A H I J K	H I D E

The positive and negative antecedents are not altogether different. 'A' is the only circumstance that is uniformly present in the positive and uniformly absent in the negative instances. All other elements that are present in the positive group are present somewhere in the negative group. The positive instances suggest that A is the cause; the negative instances show that none of the elements that appear in them is the cause. If the negative set is complete, we know that A is the sole cause. Thus we eliminate the element of uncertainty due to the Plurality of Causes. This is the characteristic feature of this Method. It shows that if A is the cause of x, it is the sole cause of x.

CHAPTER X

METHODS OF INDUCTION (ii)

III. THE METHOD OF DIFFERENCE

I. Principle of the Method.

The canon of the Method, as stated by Mill, runs as follows:—

If an instance in which the phenomenon under investigation occurs, and an instance in which it does not occur, have every circumstance in common save one, that one occurring only in the former; the circumstance in which alone the two instances differ is the effect, or the cause, or an indispensable part of the cause of the phenomenon.

Mellone states the principle in the following simple form:—

'When the addition of an agent is followed by the appearance, or its subtraction by the disappearance of a certain event, other circumstances remaining the same, that agent is causally connected with the event.'

If A B C are followed by x y z, and B C by

y z, we can infer that A is the cause, or an indispensable part of the cause of x.

This Method is essentially a Method of Experiment, and is applicable only where the phenomenon is under our control. Sometimes, as in an eclipse, Nature seems to be performing an experiment for us, but in most cases we have to resort to artificial experiment. As Mellone's statement of the canon implies, we may either introduce an agent and see what follows, or withdraw it and notice the result. Formally we may start in either way, but practically it is more convenient to introduce an agent and notice the consequence. This is so, because it is far more easy to add an element to a mixture than to withdraw it from the mixture. It is easier to mix coffee with hot water and notice the change in colour and flavour than to remove coffee from the coffee infusion and notice the result.

2. Examples of the Method of Difference.

This method is very frequently used in everyday life. A man is working quietly at his table. A dog comes from behind and bites him. He starts up and in the state of annoyance kicks the dog. The change in him is ascribed to the dogbite. A man receives a telegram and immediately upon reading it, he grows pale and his hands

tremble. The contents of the telegram, we say, have caused the mental shock and concomitant physical changes. A piece of paper is thrown into the fire. At once the colour of the paper changes. We ascribe the change to the action of fire. You go into a bath room and turn the tap. Out gushes the limpid stream of water. You press a button and the whole Boarding House is lighted. You claim credit for these effects.

This is how Professor Haffkine prepared the serum for plague inoculation. In view of the success of vaccination in preventing small-pox, he began to work out a means of preventing plague. He prepared a serum which he first tried on rats which catch plague readily. He says: 'Take twenty healthy rats got from a ship, which has come from a port where there is no plague. Inoculate ten of these rats with the serum and leave the other ten alone. Put the twenty rats all together and put a rat suffering from plague among them. It will be found through course of time that eight or nine or all the rats that have not been inoculated will die of plague, and only one or none of the inoculated rats will die.' He performed these experiments and found that the results agreed with his expectations. Then he began to inoculate human beings.

3. Cautions to be observed.

The force of this Method depends upon the assumption that only one circumstance has been introduced or withdrawn. When this condition is not satisfied, the conclusion is of no scientific value. If two agents are simultaneously introduced and there is an effect, this may be due partly or wholly to the circumstance of which we take no account. If no effect appears, the agents may not be ineffective ; they may both be effective in opposite directions and thus neutralise each other. Some patients use simultaneously a number of drugs prescribed by several men without consultation. In such cases, if the cure is effected, there is no means of ascertaining to which drug it is due ; and if there is no cure, it is not fair to conclude that the drugs are all useless.

Except in the laboratory, where we have to deal with comparatively stable things, it is extremely difficult to secure this condition. In living things which are perpetually chonging and evolving, it is almost impossible to secure two things, or even two conditions of the same thing, which are exact repetitions each of the other. If I want to know the effect of a certain drug on my system, I may use it on one occasion and compare the consequent condition with my general condition. But what is that general condition? My

condition is always changing. The health of a man depends partly upon his mood, which changes from day to day, possibly from hour to hour. 'A patient may have medicine administered to him, and begin at once rapidly to recover, and yet the very taking of the medicine in itself may have made such a mental impression, inducing confidence and hope, that the real cause of the recovery may be due wholly to this mental reaction. Persons taking pills composed of inert substances have often given evidence of bodily effects wholly impossible to trace to the medicine itself.'*

This shows that we have to be very cautious in the employment of this Method. We must take as much care as we possibly can to ensure that only one circumstance is introduced or withdrawn. A second precaution that is necessary is that we should not confound the liberating condition with the real cause. In one of the instances that we have given, the pressing of the button is not the real cause of lighting the Boarding House. The real cause is the electric force which has simply been liberated by your action. Your action can be said to be the cause of the force manifesting itself.

* Hibben, 106-07.

In the experiments that we perform, we should see that the interval of time, during which the experiment lasts, is as short as possible. This caution has to be observed, not because the mere fact of the passage of time in any way neutralises or modifies the action of the cause at work, but because only thus can we, in most cases, be sure that no other relevant condition has been introduced or withdrawn in the meantime. If you take a medicine to-day, and are cured of your disease after ten years, it is very unlikely that the medicine is responsible for the cure ; for, in the interval, so many other conditions that are operative will have been introduced.

4. Methods of Agreement and Difference—A Contrast.

Some of the characteristics of this Method will be brought out by contrasting it with the Method of Agreement.

(1) The Method of Agreement considers instances that *agree* in one point, the co-presence of a circumstance and a phenomenon ; the Method of Difference considers instances that *differ* in respect of this circumstance and the phenomenon —these being present in the one and absent in the other.

(2) In the Method of Agreement, the larger the number of suitable instances, the better it is ; in the Method of Difference, only two instances are needed.

(3) The Method of Agreement is based on the ground that whatever can be eliminated is not causally connected with the phenomenon. The Method of Difference is founded on the principle that whatever cannot be eliminated is causally connected with the phenomenon.

(4) The Method of Agreement is a Method of Observation and infers from effects to causes ; the Method of Difference is essentially an Experimental Method and infers from causes to effects.

(5) The Method of Agreement cannot prove a causal connection ; it simply suggests that connection. The Method of Difference tests this suggestion and proves the connection. The Method of Agreement can give only a *probable* conclusion ; the Method of Difference, if its conditions are satisfied, gives a *certain* conclusion.

(6) The Method of Agreement is open to the objection arising from the existence of Plurality of Causes ; the common circumstance may possibly be altogether inoperative. The Method of Difference, if its conditions are rigidly satisfied, proves that the agent under investigation is *a* cause of the

phenomenon. It does not establish that this agent is the sole cause of the phenomenon.

IV. THE METHOD OF CONCOMITANT VARIATIONS

5. Principle and Function of the Method.

'*Whatever phenomenon varies in any manner whenever another phenomenon varies in some particular manner, is either a cause or an effect of that phenomenon, or is connected with it through some fact of causation.* (*Mill.*)

Symbolic representation:—

A B C	are followed by	x y z.
$A_{,}$ B C	"	$x_{,}$ y z.
$A_{,,}$ B C	"	$x_{,,}$ y z.

A and x are causally connected.

The Method of Agreement, as we have already seen, *suggests* a causal connection between two phenomena ; the Method of Double Agreement which is only a modification of the Method of Single Agreement, *strengthens that suggestion;* and the Method of Difference *tests* the suggestion, and, if its conditions are rigidly satisfied, decisively establishes a causal connection. From this it may appear that the Method of Difference gives us all that we need. And yet a little consideration will show that this is not the case. The

Method of Difference can be applied where the cause and the effect can be wholly eliminated. Now in some cases this is not possible. All that we may be able to do is to vary the intensity of the operating conditions. In such cases the Method of Difference cannot be used, and we have to substitute for it the Method of Concomitant Variations. Thus used, the Method is meant to establish the fact of connection. But sometimes it may be our interest to *measure* phenomena. For a quantitative determination of the causal connection, the Methods hitherto considered are quite ineffective. The Method of Concomitant Variations is used not merely to establish that A and x are causally connected, but also to find how much of A is needed to produce a certain amount of x, or to establish the *law* according to which two phenomena are connected. Such enquiries are exceedingly important in practical life as well as science. We may know that quinine is useful in malarial fever, but when we are suffering from malaria, we must also know how much quinine is to be taken to bring down the present temperature. In these cases, the Method of Concomitant Variations does not function as a *substitute* of the Method of Difference; it serves as a *supplementary* Method to complete the work of the qualitative Methods.

6. Examples of the Method of Concomitant Variations.

Examples of the application of this Method abound in common life and in the history of science. An interesting instance is the proof of the first Law of Motion—the Law that all bodies in motion continue to move in a straight line with uniform velocity until acted upon by some new force. 'This assertion,' says Mill, 'is in open opposition to first appearances; all terrestrial objects, when in motion, gradually abate their velocity and at last stop; which accordingly the ancients, with their *induction per enumerationem simplicem*, imagined to be the law. Every moving body, however, encounters various obstacles, as friction, the resistance of the atmosphere, &c., which we know by daily experience to be causes capable of destroying motion. It was suggested that the whole of the retardation might be owing to these causes. How was this enquired into? If the obstacles could have been entirely removed, the case would have been amenable to the Method of Difference. They could not be removed, they could only be diminished, and the case, therefore, admitted only of the Method of Concomitant Variations. This accordingly being employed, it was found that every diminution of

the obstacles diminished the retardation of the motion.'*

In Physiology, it is now a well-established fact that intelligence is causally connected with brain development. How is this known? Obviously, we cannot remove the brain of a man and see whether he will remain intelligent. He will no longer be a living man. But human beings show differences in intelligence and in brain development, and observation shows that these two vary concomitantly. 'Dr. Thurnam taking the brainweights of ten distinguished men, who died between the ages of fifty and seventy, calculates the average weight of their brains to have been 54·7 ounces. The average weight of the brains of ordinary men, dying between the same ages, is 47·1 ounces.' (Fowler.)

We may ring a bell in a vacuum and hear no sound. Let us allow the air to enter gradually. As the air enters more and more, the sound grows louder and louder. The relation of cause and effect between the presence of air and audibility of sound is here clearly established.

If we place a rat in the receiver of an air pump and begin to exhaust the pump, we shall find the animal getting more and more oppressed

* Logic III, VIII, 7.

as the exhaustion proceeds. This shows that the air, or some element in it, is essential to sustain animal life.

Heat expands bodies. As you heat a metallic ball, its volume increases. The thermometer not only shows the effect of heat in expanding bodies but also gives a quantitative determination of this relation. It is in virtue of this that it has become almost a necessity of civilised life.

7. Cautions to be observed.

There are two precautions that must be taken in the employment of this Method. In the first place, when two phenomena vary concomitantly, we should not, without further evidence, jump to the conclusion that one is the cause of the other. They may both be effects of one and the same cause. This is admitted in the last clause of the canon.

Secondly, this Method does not justify our going much beyond our actual observations. To use technical language, the Method gives us an Empirical Generalisation rather than a Law of Nature. The mode of the change that we observe between certain limits may not continue beyond those limits. A very interesting example is found in the effect of cold on water. Water contracts as it cools. If we take water at 80°F., and lower its

temperature to 70°F., the volume will be decreased. If the temperature is lowered down to 60°F., water contracts still further. This continues till we reach 40°F. When we lower the temperature to 39°F., water begins to expand and this expansion continues, till we reach the freezing point 0°F., where it becomes solid. If your experience within certain limits is that the more work one puts in, the better results one shows, it would be rash to infer that this will also hold much beyond these limits.

V. THE METHOD OF RESIDUES

8. Principle of the Method.

'*Subduct from any phenomenon such part as is known by previous inductions to be the effect of certain antecedents, and the residue of the phenomenon is the effect of the remaining antecedents.*'

(Mill.)

If A B C D E produce x y r s t ; and A produces x and B C produce y r ; we may conclude that D E produce s t.

This method is a modification of the Method of Difference and possesses its decisiveness. In the above representation we have assumed that the effect is as heterogeneous as the cause. Sometimes

it happens that the effects that a number of causes produce are of the same type and mingle with one another. These are cases of Homogeneous Intermixture of Effects. Where such is the case, the Methods that we have so far described can render no help. If we know by previous inductions that certain elements in the total cause produce a certain part of the effect, we can infer, according to the Method of Residues, that the remaining part of the effect is due to the remaining causes. Elementary arithmetic abounds in exercises based on the principle of this Method. If A, B and C can do a piece of work in 10 days ; A alone can do it 30 days, and B alone in 20 days : we can find the time that it will take C to do it.

9. Method of Residues as an Instrument of Research.

In Science, this Method has proved an excellent instrument of research. Scientists find that a certain part of a complex phenomenon is still unexplained by the causes which are known to be working. This part, known as the *residual phenomenon*, must be due to some further cause which must be sought. It is thus that some of the greatest discoveries in Science have been made. Perhaps the most striking illustration of the Method is the discovery of the planet Neptune by

Adams and Le Verrier. 'These astronomers had observed certain perturbations in the planet Uranus. It did not keep in its proper orbit as determined by their mathematical calculations based upon the presence of the known stellar bodies. It behaved as though beyond its orbit was an outer planet, whose presence alone could account for the observed perturbations. Adams and Le Verrier then proceeded to calculate the exact position of such a disturbing body as determined by the nature and magnitude of the perturbations of Uranus. The telescope was then pointed to the exact point in the heavens, as thus indicated, and the planet Neptune was revealed to the eye according to the determination of a far reaching prophecy, which confidently asserted that it must be there.'*

10. Its Place in Induction.

The Method of Residues is deductive in nature. It is based on the law of sufficient reason —some elements produce a certain result ; a part of the antecedent-elements are responsible for a part of the result, and we argue that the remaining elements are responsible for the remaining part of the result. We mention the method

* Hibben, 147.

here because it is based on previous inductions and leads to investigations that can be prosecuted by the inductive Methods. It is a link in an inductive enquiry.

11. Application of the Methods.

The following examples will indicate the method of determining causal relations of elements occurring in the given sets of antecedents and consequents :—

Given the following sets of antecedents and consequents, what conclusion can be drawn and on what grounds ?—

X Y W U	..	h g j k	(1)
Y Z W	...	j h i	(2)
Y P Q	...	e j f	(3)
X W U	...	g h k	(4)
Y R O	...	a j d	(5)
X Y P Q	...	k j f e	(6)
X Y U	...	k j g	(7)

(P. U. 1917)

We have	X Y P Q	...	k j f e	(6)
and	Y P Q	...	j f e	(3)
∴	X	...	k (Meth. of Dif.)	(A)
Again,	X Y W U	...	h g j k	(1)
and	X W U	...	h g k	(4)
∴	Y	...	j (Meth. of Dif.)	(B)

Again,	X Y W U	...	h g j k	(1)
and	X Y U	...	g j k	(7)
∴	W	...	h (Meth. of Dif.)	(C)
Again,	X Y U	...	k j g	(7)
and	X Y	...	k j (A & B)	
∴	U	...	g (Meth. of Res.)	(D)
Again,	Y Z W	...	j h i	(2)
and	Y W	...	j h (B & C)	
∴	Z	...	i (Meth. of Res.)	(E)

Thus the causal relations found are—

X—k
Y—j
W—h
U—g
Z—i

By comparing (B) with (3) and (5), we are able to say that PQ are jointly responsible for e f and RO for a d ; but beyond this we cannot go.

What causal relations are suggested by the following combinations?

A B C F N O P Q	(1)
C D E G L M N T	(2)
C H I J N R S	(3)
B C E N O T	(4) (Aikins.)

Here we observe that the circumstances C N are present in all the combinations, and they are the only common circumstances. They are, there-

fore, probably causally connected. (Method of Agreement.) Combinations (1) and (4) show the co-presence of B and O, and combinations (2) and (3) show the co-absence of these two circumstances. Therefore, they, too, are probably causally connected. (Method of Double Agreement.) If these two suggested causal connections do really exist, the combination (4) shows that E and T are causally connected. (Method of Residues.) This connection is also suggested by a comparison of combinations (2) and (4).

12. Discovery and Proof.

After this brief survey of the nature of the Experimental Methods, we may now refer to their ultimate aim. Whewell supposes that Induction is primarily the art of Discovery ; Mill thinks that it is essentially a theory of Proof. According to Whewell, our object is to find cases where *a* and *b* are connected; according to Mill, our main business is to see whether the connection that is assumed to exist can be shown to be really existing. 'The great generalisations which begin as Hypotheses must end by being proved, and are in reality proved, by the Four Methods. It is with Proof as such, that Logic is principally concerned.'

Whewell objects against these Methods that

'they take for granted the very thing which is most difficult to discover, the reduction of the argument to formulæ such as are here presented to us. . . . You say, *when* we find the combination of A B C with *a b c* and A B D with *a b d*; then we may draw our inference. Granted; but when and where are we to find such combinations?' In answer to this, Mill refers to a similar objection raised against the syllogism, that the great difficulty is to obtain the syllogism, not to judge of its correctness when obtained. 'The great difficulty in both cases,' says Mill, 'is first that of obtaining the evidence, and, next, of reducing it to the form which tests its conclusiveness.'' This does not show, however, that the process of testing is unnecessary or unimportant in either case. 'The business of Inductive Logic is to provide rules and models (such as the syllogism and its rules are for ratiocination) to which, if inductive arguments conform, those arguments are conclusive, and not otherwise. This is what the Four Methods profess to be, and what I believe they are universally considered to be by experimental philosophers, who had practised all of them long before any one sought to reduce the practice to theory.'*

* Mill: Logic, III, ix. 6.

Mill makes estimation of evidence the chief function of these Methods, and discovery a subordinate function. All Methods of Proof must indirectly aid the task of discovery. By means of them we examine hypotheses and, if these are found untenable, we are led to the discovery of true explanation. Taking the Methods individually, we have seen that the Imperfect Inductions only suggest the existence of a causal connection. They have some value in the Logic of Discovery, but little value in the Logic of Proof. The Method of Agreement strengthens this suggestion. The Method of Double Agreement, which is but a modification of the Method of Single Agreement, furnishes a better clue to the discovery of a causal connection, and *proves* that if A is the cause of x, it is the sole cause of it. The Method of Difference is the chief method of proving a causal connection that has been suggested by the other methods. The Method of Concomitant Variations enables us to find the Law according to which, within certain limits, phenomena vary. The Method of Residues, as has been shown above, has proved a very valuable instrument of Scientific Research.

13. The Art of Discovery.

The art of Discovery embraces Facts and

Reasonings on Facts. Facts are obtained by active search for them. Methods of discovering facts have been mentioned in the chapter on Observation and Experiment. Inferences from facts or generalisations may be obtained by comparing facts. Bain lays down the following rules for the discovery of generalities—

"(1) The *number* of instances should be as extensive as possible. In the comparison of a large number the mind will be struck with points of community, from the very fact of the recurrence ; as the examples collected in the research on Dew. Moreover, there will start forth some one that contains the circumstance sought in startling prominence ; these are the glaring or suggestive instances. Such, in the case of Dew, was the example of the warm breath upon a cold iron surface, as a knife blade."

"(2) When out of mere number and variety of instances, the identity does not flash upon the mind, the next thing is to *select* a few for careful scrutiny. Each instance should be studied in isolation, should be gone over in every minute point, and examined from every side ; the features being exhaustively set down in writing. After a few separate instances have been considered in this thorough way, the resemblances (unless at the time inscrutable for want of other lights) will

become apparent to the view. Newton's study of the phenomenon of the coloured rings of the soap-bubble was an exercise of the severe mental concentration now described."

(3) "The general laws of phenomena must be sought in the cases where they are *least complicated* or combined with other laws. This is an obvious precaution conducing to Discovery. The laws of motion are studied in simple cases; such as straight-lined movements; or wheel-movements, under a single impulse. Gravity is best studied in bodies falling perpendicularly, where there is no other force operating. Neither the first law of motion, nor the law of gravity, could have been advantageously generalized in the flow of rivers, or in the motions of the planets."*

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* Inductive Logic, 96.

CHAPTER XI

THE DEDUCTIVE METHOD OF INVESTIGATION

1. Limitations of the Inductive Methods.

We have seen that Simple Enumeration and Analogy suggest the hypothesis of a causal connection between phenomena, and the Inductive methods seek to establish that hypothesis. We have assumed that these facts, causes and effects, are open to observation and can be manipulated as we desire. This is by no means always the case. The ultimate causes with which science deals, e.g., atoms or electrons and ether, are hidden from our view, and, therefore, the Inductive Methods cannot take us a long way. Further, all that they can give us is an Empirical Generalisation—a statement of how facts are connected. They cannot explain their connections. Now Explanation is the goal of science. Besides these Methods, we require a Method of Explanation. The effect in many cases is exceedingly complex and is produced by a large number of antecedent conditions working together. This

is particularly the case in physiological and sociological phenomena. When we have to deal with such phenomena, the Inductive Methods prove hopelessly inadequate. We thus see that in several cases the Inductive Methods are either inapplicable or of very limited utility.

2. The Deductive method of Investigation.

These defects are remedied by what Mill calls the Deductive Method. 'The problem of this Method is to find the laws of an effect from the laws of the different tendencies of which it is the joint result.' As in other Methods, we may read facts forwards or backwards. We may have to answer either of the following two questions—Given a certain combination of causes, what effect will follow? and, what combination of causes, if it existed, would produce a given effect?

The Method consists of three operations:—

(1) Direct Induction.
(2) Ratiocination.
(3) Verification.

The first process—Direct Induction—aims at finding the laws of various causes that are working jointly in the present case. This can be done by employing the methods of Induction, for probably each of these causes occurs in other

circumstances also. If I want to know in which direction and at what rate a boat will move, I must ascertain what kind of motion each one of the agents working upon it—the rowers, the current of the stream, the wind, etc.—will produce, if it were to work alone.

The second process—Ratiocination—is the calculation of the joint effect of the causes when their respective effects are known. In theory, this seems to be simple enough ; but, in practice, we shall find that the results that we can find are only approximate. 'In the case of the motion of a projectile, the causes which affect the velocity and range (for example) of a cannon-ball may be all known and estimated ; the force of the gunpowder, the angle of elevation, the density of the air, the strength and direction of the wind ; but it is one of the most difficult of Mathematical problems to combine all these, so as to determine the effect resulting from their collective action.' (Mill.)

The difficulty in complex cases arises from two causes—(1) we cannot be sure that all the agents that are operating have been taken into our reckoning. Where so many agents are working, it is likely that some are overlooked. (2) Even if all the agents are recognised, we require the laws of combination of effects. Simple sum-

mation will not do. When two forces working in the same plane act on a point, it will move in the line of the diagonal of the parallelogram of which the sides may represent those forces. This is a very simple case. In complex cases, the laws of combination are not so clear.

Is the difficulty insurmountable? No ; for there is a test by which we may see whether any error has been committed. This test is the third process in the method. Unless the calculations that are the result of the second process are verified, they are no more valuable than mere conjecture. When careful observation shows that the results of Ratiocination tally with facts, the hypothesis is confirmed.

To the Deductive Method with its three parts, Induction, Ratiocination and Verification, Mill attaches the greatest importance. To it, he says, 'the human mind is indebted for its most conspicuous triumphs in the investigation of nature. To it we owe all the theories by which vast and complicated phenomena are embraced under a few simple laws which, considered as the laws of those great phenomena, could never have been detected by their direct study.'

This Method is known as the Method of Explanation in contrast to the Inductive Methods which are the Methods of Observation ; Methods

that is, which tell us how facts that we can observe are causally connected.

3. The Hypothetical Method.

In his exposition of the Deductive Method, Mill assumes that we are aware of the causes that are working in a given case, and our business is to find the effect that they will conjointly produce. Sometimes we are not in possession of this knowledge. It is, in fact, the object of our quest. We know the effect and are anxious to know the causes that have led to it. This requires the employment of Hypothesis, and the method that is used may be called the Hypothetical Method. Jevons calls it the Complete Scientific Method, and distinguishes the following four steps in it :—

1. Preliminary Observation or Rude Induction.
2. Hypothesis.
3. Deduction of consequences from the Hypothesis.
4. Verification.

The nature of the Hypothetical Method may be explained by the following examples :—

(*i*) *James' Theory of Emotions.*—James starts with the familiar fact that many a time a sudden reverberation of our body takes place, and

this is followed by the appearance of an Emotion of fear or terror. Instances of such unmotived fear are frequently met with in the case of insane persons. They are often in terror when really there is nothing outside to cause the terror. On examination, it is found that somehow bodily changes, that are ordinarily taken to be accompaniments or expressions of terror, take place and they are followed by the emotion of terror.

On the basis of these observations, James advances the hypothesis that *all* Emotions are consequences of bodily changes. 'Our natural way of thinking about coarser emotions is that the mental perception of some fact excites the mental affection called the emotion, and that this latter state of mind gives rise to the bodily expression. My theory, on the contrary, is that the *bodily changes follow directly the perception of the exciting fact, and that our feeling of the same changes as they occur is the emotion*. Commonsense says, we lose our fortune, are sorry and weep; we meet a bear, are frightened and run ; we are insulted by a rival, are angry and strike. The more rational statement is that we feel sorry because we cry, angry because we strike, afraid because we tremble.'

How can this hypothesis be proved? If we could find a man who had lost all feeling but re-

tained the power of acting so that emotion-inspiring objects might evoke the usual bodily expression from him, we could, by comparing him with a normal man, prove the theory. Such a man would be like one who eats without being hungry.

As we cannot find such a men, we must prove the hypothesis indirectly : that is, see if corollaries drawn from it are verified. If this hypothesis be correct, it should follow that if we voluntarily arouse the so-called manifestations of an Emotion, the Emotion itself will be produced ; and, on the contrary, if we suppress the expressions, the Emotion will vanish. James maintains that experience corroborates this corollary. 'Every one knows how panic is increased by flight, and how the giving way to the symptoms of grief or anger increases those passions themselves. Each fit of sobbing makes the sorrow more acute, and calls forth another fit stronger still. In rage it is notorious how we 'work ourselves up' to a climax by repeated outbreaks of expression. Refuse to express a passion and it dies. Count ten before venting your anger, and its occasion seems ridiculous.'*

(ii) *Diagnosis of disease.*—A man has had

* James : Principles of Psychology, II, 462-3.

a rather high fever for some days. The doctor examines him and, by noticing some analogy between the present case and the cases of typhoid fever that have come under his notice, is inclined to believe that the disease in this case also is typhoid fever. Analogy has suggested this hypothesis. But is it typhoid fever? The symptoms are not decisive. Typhoid fever is due to a particular kind of bacilli. Can these be detected in the blood of this patient? It may be that the medical man is not competent to examine the blood; or that, within ten days of the attack, the examination will not show the presence of the bacilli. In such a case, all the doctor can do is to treat the patient on the assumption that it is a case of typhoid fever. If the results tally with his anticipations, his hypothesis is confirmed. Much of what is known as scientific treatment is this kind of experimenting. Many a time the doctor has to revise his hypothesis. Sometimes the revision comes too late for the poor patient.

CHAPTER XII

HYPOTHESIS

1. What is an Hypothesis?

'An hypothesis,' says Mill, 'is any supposition which we make (either without actual evidence, or on evidence avowedly insufficient) in order to endeavour to deduce from it conclusions in accordance with facts which are known to be real; under the idea that if the conclusions to which the hypothesis leads are known truths, the hypothesis itself either must be, or at least is likely to be, true.' Here Mill gives us the characteristics of what may be called a scientific or valid hypothesis. The use of hypothesis, however, is not limited to scientific enquiries. One of the strongest tendencies in man is the tendency to explain facts. Even the primitive man seeks to account for or explain what appears strange to him. It is true that some of his explanations appear extremely crude or absurd to us, but who knows that the explanations that satisfy us may not be pronounced absurd by an intelligence of a higher order? The essential point is that he

too asks the 'why' of some phenomena. Why does it rain? Why does the sun rise every day? Is it the same sun that rises every day? Why do the stars shoot? Such questions in all probability never occur to the brutes; they do occur to the savage, and the savage attempts to find an answer. In every-day practical life, we frame hypotheses that do not satisfy the conditions enumerated by Mill. Common-sense makes hypotheses for practical purposes; science seeks to discover causes of effects and to connect these causes by means of laws. In order that an hypothesis may be scientifically valid, it has to satisfy conditions that may not be satisfied by an hypothesis of common-sense. The essential feature of all hypotheses is contained in the first part of Mill's description. An hypothesis is a provisional explanation of facts; the evidence for it is either non-existent or avowedly insufficient. The framer of the hypothesis at least thinks that the explanation has some plausibility.

We shall confine ourselves to the study of Scientific Hypotheses.

2. The function of Hypothesis.

Hypothesis, as used in science, performs a twofold function. In the first place, it suggests a definite line in which experimental work may

proceed. 'It is allowable, useful and often even necessary, to begin by asking ourselves what cause *may* have produced the effect, in order that we may know in what direction to look out for evidence to determine whether it actually *did*.' (Mill.) In the absence of such a suggestion, an investigation must be quite indeterminate and haphazard. Of a number of circumstances that may be taken to be causally connected with a phenomenon, the scientific man discards some as irrelevant and confines his examination to a few. He thus narrows the bounds of his enquiry. Secondly, hypothesis is employed when owing to the special conditions of the phenomenon, experiment or systematic observation is out of the question. In the last chapter, we saw how hypothesis is used as a stage in the Deductive Method. This method is generally employed in Sociology, History, Geology and Astronomy.

As an illustration of the first function of hypothesis, we may mention the discovery of vaccination by Jenner. It seems that while a mere youth, pursuing his studies at Sodbury, he chanced to hear a casual remark made by a country girl who came to his master's shop for advice. The small-pox was mentioned, when the girl said, 'I cannot take that disease, for I have had cow-

pox.' This observation, expressing the common superstition of the simple country folk, appeared to Jenner's mind as an inchoate hypothesis. Seizing upon it, as a suggestion of possible value, he proceeded to make diligent enquiries and careful observations, which finally led him to the discovery of vaccination.*

3. Conditions of Validity in an Hypothesis.

Every fancy of the human mind is not an hypothesis in the scientific sense. As we have seen above, the framer of the hypothesis must suppose that the hypothesis is a plausible explanation. The belief alone, however, will not make an hypothesis legitimate. In order that an hypothesis may be valid, it must satisfy the following conditions :—

(1) The hypothesis must be based on facts and must not be known or suspected to be untrue, *i.e.*, to be inconsistent with facts already ascertained or inferences which can be drawn from them.

An hypothesis comes into being only as a provisional explanation of facts. We should be sure therefore, that what we want to explain are facts and not fictions. Before beginning to answer such questions—' why is a dead body heavier than

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* Hibben : Inductive Logic, 177.

a live body?' 'why do some men smell through their eyes?' we should assure ourselves that such things do happen. Again, an hypothesis that is inconsistent with known facts or inferences drawn from them condemns itself as worthless. An hypothesis that is in contradiction to the Law of Gravitation or elliptic movement of the planets will not be entertained by a man of science to-day. Here, again, we must be very careful about our 'facts'; for the fact may be that the new hypothesis conflicts only with an older hypothesis and not with facts. Many a time we have only to modify the old hypothesis in the light of fresh knowledge. All that is essential is that we never lose sight of the fact that Nature is one system and Truth about it also is one.

(2) As Mill suggests, a valid hypothesis must be capable of being verified. That is, we should be able to deduce consequences from it and see whether they do or do not tally with facts. An hypothesis that is to remain for ever an unverifiable conjecture is illegitimate. Appeals to the agency of angels in the causation of astronomical phenomena are not allowed in science, because though the existence of pure spirits is possible, we cannot know anything about them by employing the ordinary empiri-

cal methods. The hypothesis of their intervention can be neither proved nor disproved.

(3) The hypothesis should be adequate to explain all the facts that demand an explanation. This condition must be satisfied, because we start with the assumption that Nature is a system and every fact fits in it. When some new facts come to our notice which refuse to harmonise with the hypothesis, the hypothesis has to be modified.

As an example of an illegitimate hypothesis, Stock mentions the hypothesis of the ancients that the fires of Mount Aetna were due to the giant Typhoeus chained beneath it. This hypothesis, says Stock, fulfils none of the Conditions of a valid hypothesis, for

(1) Typhoeus is a fiction of the poets ;

(2) that he should breathe fire from his lungs contradicts what we know of the laws of nature ;

(3) even granting that he did, could he go on breathing fire age after age?

(4) this would account only for one valcano ;

(5) it defies investigation.

Contrasted with this, the hypothesis of a central fire 'not only accounts for volcanoes, but also for hot springs and the heat of mines and

is consistent with what we know of the nature of heavenly bodies.'*

How are earthquakes caused?

Two hypotheses may be mentioned as alternative explanations. According to the one, the shock is experienced when the bull that supports the earth shifts it from one horn to the other. According to the other the phenomenon is due to the changes that take place deep below the surface owing probably to the internal heat.

Which of the two hypotheses is valid and why?

4. Confirmation and proof of an Hypothesis.

We must distinguish beeween the confirmation and the proof of an hypothesis. If the conclusions drawn from an hypothesis tally with facts, the hypothesis is confirmed but not yet proved. The reasoning may be thrown in the following form—If A, then B.

B.

?

No conclusion can be obtained by affirming the consequent of the hypothetical Major. In Inductive enquiry, we may refer the difficulty to the plurality of causes. B may be due not

* Logic : 201-2.

only to A, but also to some other cause, and in the present case that cause may be working. In order that an hypothesis may be completely established, it must be shown that no other hypothesis can explain the fact or facts in question.

As an illustration, we may take the following case :—

"An old woman engaged in the curious business of pledging and redeeming articles of pawn was murdered. In one hand of the corpse were discovered three hairs, which, it was surmised, the poor old body in her death agony had torn from the head of her assailant. Forthwith the hairs were delivered to two very noted microscopic experts. In prison under suspicion of the crime lay the old woman's son, of whose hair also some samples were sent to the examiners. 'The three hairs found in the hand of the corpse were from six to seven cms. in length, were dark brown in colour, had been torn out (the roots were preserved), and seemed to have belonged to a man from twenty to forty years old.' What struck the experts as somewhat strange was that, while two of the hairs were brown under the lens, the third was in some parts brown and in others black. 'Just above the root it was brown, half a centimetre farther on it became black, then again brown and half a centimetre

farther towards the tip it became black again.' The phenomenon is said to be of very unusual occurrence. Next were analysed the samples of hair cut from the head of the prisoner, and behold! the fantastic phenomenon repeated itself. About 'two-thirds of the hairs were brown and the other third presented absolutely the same peculiarity as the brown and black striped hair' found in the dead woman's hand."*

Here was a good confirmation of the hypothesis that the woman had been murdered by her son. But the hypothesis was not proved, for the possibility that some other man's hair also presented the same peculiarities was not ruled out. As a matter of fact, the man was not the assasin. The real assasin was caught and the microscope showed that his hair was very nearly identical with that of the murdered woman's son.

5. Crucial Instances.

We have said above that in order that an hypothesis may be said to be established, it is essential to show that this alone can explain the facts of a particular class. Now, it often happens that two or even more hypotheses can explain a great number of the facts in question. In such cases,

* T. Hopkins : Wards of the State, 149—150.

we are in search of some fact or facts which only one of the hypotheses can explain. These will confirm one hypothesis and at the same time negative the rival hypothesis or hypotheses. Such facts are called Crucial Instances. If they are arrived at by experiment, the experiment is known as *experimentum crucis* (Finger-post experiment). A medical man was asked whether a baby was suffering from typhoid fever or pneumonia. His answer was that in case of infants the symptoms of these two disease are difficult to discriminate, but as the temperature fell instead of shooting up in the second week, the disease was not typhoid fever. If he was well-informed, he was referring to a crúcial test.

CHAPTER XIII

EMPIRICAL LAWS AND LAWS OF NATURE

1. Three Classes of Laws.

The generalisations that science secures are of varying degrees of probability. In **Scientific Laws,** the causal relation between antecedents and consequents is definitely established. In the second class, known as **Generalisations of Probability,** we find that there are exceptions that break the regularity of sequence. Our experience gives us some information about the relative frequency of cases where the relation holds and where it does not hold, and we infer that in the unexamined cases also this proportion between cases of both kinds will hold. Suppose I have one thousand papers to examine, and find that of the first six hundred, forty per cent. pass, ten per cent. being placed in the first class. I infer that the remaining four hundred papers also will show similar results. The third class of Laws, called **Empirical Generalisations,** stand

intermediate between the first two classes. Here, so far as we have observed, no exception has been noted, but there is nothing to show that no exception can exist. A uniformity has been observed, but no causal relation has been established, and we are prepared to admit that the very next case that comes before us might be an exception. As a rule, all causal laws pass through this stage, and progress in scientific knowledge is characterised by nothing more than by the substitution of Scientific Laws for Empirical Generalisations. Some Logicians, however, are of opinion that there is no real difference of kind between Scientific Laws and Empirical Generalisations. Progress in scientific knowledge means the substitution of wider Generalisations for the narrower ones. According to Venn, all Laws are Empirical. In the preface to his Empirical Logic, he says, 'By the introduction of the term Empirical into the title, I wish to emphasize my belief that no ultimate objective certainly such as Mill, for instance, seemed to attribute to the results of Induction, is attainable by any exercise of the human reason.'

2. The Nature of Empirical Laws.

'There are three essential marks,' says Boyce Gibson, 'which must be included in the

definition of an Empirical Law. In the first place, it must have been gained through direct observation of facts. In the second place, it must not already have been explained as a particular case or specification of some law more fundamental than itself ; it is a law, in fact, which has not itself been systematised. Thus Kepler's Laws of Planetary Motion were empirical in this sense *until* Newton showed that they were necessary deductions from his own principle of universal gravitation. They then became specifications or expressions of the Law of Gravitation. In the third place, the Empirical Law is not an Explanatory Law. It is a law *descriptive of the behaviour of facts* without at the same time being explanatory, or descriptive of the mode or behaviour of a cause.'*

3. Kinds of Empirical Laws.

(i) We have said above that causal laws pass through the stage of empirical generalisations. When a connection between phenomena has been uniformly observed but has not yet been proved, the Scientific Law may be said to be in the making. The Laws of causation, *so long as they are at the empirical stage*, are empirical

* Problem of Logic, 341-2.

laws. In the passage from Boyce Gibson quoted above, Kepler's Laws of Planetary Motion are mentioned as Empirical Laws *until* Newton proved them to be special cases of the Law of Gravitation.

(ii) Sometimes effects are due to conditions that are so mixed up with irrelevant circumstances that we cannot isolate them from their immaterial concomitants. In such cases, a uniform connection is observed, but no causal relation can be established. 'The effect of certain medicines upon the human system, the local action of tides at various places on the earth's surface, the adaptation of certain plants to a peculiar kind of soil, the re-appearance of some chronic disease, as hay-fever, at the same season each year, even to the very day of the month, all such generalities have merely an empirical weight, and the effects mentioned are largely due to collocations that cannot be definitely determined.'*

(iii) An individual has an aggregate of properties, amongst which no causal connection can be found. We find glass to be transparent and brittle ; gold, yellow and malleable and 19 times as heavy as water ; birds without teeth and with feathers. We cannot say, however, why

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* Hibben : Inductive Logic, 253.

these properties should be conjoined. That they go together is an Empirical Generalisation.

4. Laws of Nature.

What is a Law of Nature? The word Law suggests to us, in the first place, a rule of conduct, proclaimed by a Government and enforced by means of penalties attached to its violation. In the words of Austin, a Law is 'a rule laid down for the guidance of an intelligent being by an intelligent being having power over him.' Such a rule implies a *command* on the one side, and a *duty* on the other. Such are the Laws of a country. Sometimes society in its non-political aspect also enforces some Laws. A community demands that the individual shall behave in a particular way in his communal relations. If the individual defies the community, he is excommunicated. These rules of conduct are Social Laws. Again, we speak of Moral and Religious Laws. In these also the relation of authority and obligation is implied. When we use the word Law in Science, we have to divest it of all suggestions of this kind. *Law in Science does not mean a command but a Uniformity.* When we can say that certain phenomena always happen in a certain manner, we have got a Law. The Laws of

a country can be violated and also modified. The Laws of Morality or Religion can be violated but cannot be modified. If truth-telling is a duty, it is always a duty, though many men can and do lie. The Laws of Nature can be neither violated nor modified. Political Laws are in the form of *must*, Moral and Religious Laws are in the form of *ought*, but a Law of Nature is in the form of *is*.

If the Uniformity refers to the behaviour of *facts*, we have an Empirical Law; if it refers to the behaviour of some *cause*, we have a casual law or a Law of Nature. As we have said before, an empirical law is not to be regarded as the final form of knowledge. The goal of Inductive investigation is to establish a causal connection between facts : it is only thus that facts can be said to be truly explained.

Some Logicians think that the Laws of Nature operate independently of man's knowledge. Man *discovers* them, but his discovery of them is not essential to their nature. They exist and operate without being known. Others are of opinion that these laws are the *formulæ* which man invents to bind facts. Apart from man's formulation of them, they have no being. The Law of Gravitation, according to this view, was not *discovered* but *invented* by Newton.

These Logicians prefer to use the word Formulæ rather than Laws.

5. Fundamental Laws of Nature.

Laws of Nature may be Derived or Fundamental. Derived Laws can be shown to be particular applications of laws that are fundamental. Karl Pearson gives the following criterion of Fundamental Laws :—'The wider the range of phenomena embraced, and the simpler the statement of the law, the more nearly we consider that the scientist has reached a fundamental law of nature.' 'The progress of science,' he continues, 'lies in the continual discovery of more and more comprehensive formulæ, by aid of which we can classify the relationships and sequences of more and more extensive groups of phenomena. The earlier formulæ are not necessarily wrong ; they are merely replaced by others which in briefer language describe more facts.'*

6. Examples of Laws of Nature.

We may close this chapter by mentioning a few Laws of Nature. These will be selected from Physics, Chemistry, Psychology and Sociology.

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* Grammar of Science, 96.

(i) **Physics.**

Law of Gravitation.—Every two bodies or portions of matter in the universe attract each other with a force directly proportional to the quantity of matter they contain, and inversely proportional to the squares of their distances.

(ii) **Chemistry.**

Law of Definite Proportions.—When two or more elements combine to form a compound, they always mix with one another in definite proportions.

Illustration : If Hydrogen and Oxygen are put together and an electric current is made to pass through the mixture, two parts of Hydrogen will combine with one part of Oxygen and the surplus of either will remain unutilised.

(iii) **Psychology.**

Law of the Threshold.—In order that a stimulus may be able to produce a sensation, it must pass a certain limit.

Illustration : If you put a tea-spoonful of sugar in a large reservoir of water, you cannot perceive the presence of sugar by taste.

(iv) Sociology.

The aggregation of a large number of individuals tends to weaken the sense of responsibility in each and to make them easily excitable.

The behaviour of mobs, in actual life or in Literature, shows that whereas an insane individual is a rare thing, a sane mob is even rarer.

CHAPTER XIV

EXPLANATION

1. Nature and Function of Explanation.

'Scientific Explanation,' says Jevons, 'consists in harmonising fact with fact, or fact with law, or law with law, so that we may see them both to be cases of one uniform law of causation.' This means that we may have to explain facts or laws, and facts may be explained by other facts or by laws. 'If we hear of a great earthquake in some part of the world and subsequently hear that a neighbouring volcano has broken out, we say that the earthquake is thus partially explained.' An indifferent student passes high in an examination. The fact is explained, if we are told that he is unscrupulous, had a clever fellow as his neighbour, and an incompetent supervisor to watch over him. We explain the fact of the tides by bringing it under the Law of Gravitation. Laws can be explained by other Laws. Mill confines his discussion of the subject to the explanation of Laws. However, there is no essential

difference between these two types of explanation —explanation of facts and explanation of Laws. In either case we seek to connect the known facts (isolated or collected under a law) with other facts.

Explanation, we have said, is the goal of science. In every-day life also we are constantly in search of explanation of facts. Why do we want to explain facts at all? There are two motives for this search. We are naturally inquisitive and when we observe a fact, we want to know more about it ; we are anxious to know what has produced it. Another motive is the importance of this knowledge in practical life. When we know the 'why' of an event, we can, to some extent, control the event, and, so far as this event is concerned, be masters of our fate. One of the chief differences between a man and a brute is that whereas the brute is at the mercy of his environment, man can to a large extent mould his environment. This difference is largely due to the fact that whereas the brute accepts the world as he finds it and simply stares at it, man thinks about it and wants to know the 'why' of things.

Men being at different levels of intellectual development, the explanations that satisfy them are also different, but in each case the effort is to

take a fact out of its *isolation* and connect it with other facts. As has been said in a previous chapter, Science regards Nature as a system. A fact is said to be explained when it is assigned a place in that system, when it is systematised. A law of Nature is explained when some other law or laws are pointed out of which this law is a particular case and from which it can be deduced.

2. Various Forms of Explanation.

Scientific Explanation assumes various forms. The more important of them are the following :—

(i) Subsumption or Generalisation.

Facts may be explained by being brought under laws, and laws themselves may be explained by being brought under wider laws. Why does this stone fall to the ground? The question may be answered in various ways—'because all stones fall'; 'because the stone is heavy'; 'because the earth attracts it'; 'because of Universal Gravitation.' In all these answers an attempt is made to connect the fact of this stone's falling with some other fact or facts. The first answer simply states that this stone is not unique in this behaviour; the second suggests that the stone is the agent of the motion; the third suggests that

the earth is the active agent and the stone the patient ; the fourth says nothing about their being agent or patient ; but one thing it does say and that is very significant. The words Universal Gravitation indicate that this behaviour is common not only to stones, to heavy bodies, to earthly bodies, but to all material things. This last Generalisation covers a vast number of facts, and the fact in question, that this stone falls, is shown to be one like innumerable other facts.

The mere repetition of an event makes us familiar with it and at home with it. The sun shines every day. Very few persons feel the need of explaining the phenomenon. We say, of course, it shines; it has been shining in the past. Now and then it is not all bright—it is eclipsed. An explanation is demanded of this phenomenon. What has become common-place seems to need no explanation. When we come across something unfamiliar, we want to understand it, and we think we understand it when we render it familiar. This is the meaning of explanation in common parlance. In Science, the process often does the contrary. As Mill says, 'it resolves a phenomenon with which we are familiar into one of which we previously knew little or nothing ; as when the common fact of the fall of heavy bodies was resolved into the tendency of all particles of

matter towards one another. In science, those who speak of explaining any phenomenon mean (or should mean) pointing out not some more familiar, but merely some more general phenomenon, of which it is a particular exemplification; or some laws of causation which produce it by their joint or successive action, and from which therefore, its conditions may be determined deductively.'

(ii) Resolution of the Complex into the Simple.

This is by far the most usual form of explanation. A complex phenomenon may be said to be explained when we can show that it can be resolved into some elements which can be individually explained by known causes. Most things when they are unsupported fall to the ground. But a balloon rises in the air. Why does it behave thus? To say that it rises in the air because it is light is no satisfactory explanation. We demand a better account and get the following reply—' The balloon is acted on, downwards, by its own weight and by the pressure of the air on its upper surface; it is acted on, upwards, by the pressure of the air on its under surface. The latter being the greater, the balloon must rise.' (Venn.) Mercury rises in the barometric tube to a certain height and no further. Why does it

rise at all? And rising, why does it stop at a certain point? The mercury in the cup below is under the pressure of the column of air above it and rises in the *empty* tube on account of that pressure. When the column of mercury in the tube can just balance the atmospheric column outside, mercury in the tube stops rising any further.* We explain the phenomenon of tides when we resolve it into effects due to the attractive forces of the sun, the moon and the earth, exerted on the water of the ocean. We explain the character of a man when we show it to be the resultant of the various tendencies that have been at work in moulding him.

(iii) **Interposition of Intermediate Links.**

Explanation of a fact ordinarily means naming its cause. Now, it often happens that what we are content to accept as the cause of a phenomenon is separated from it by an interval of time. It is not the cause of the phenomenon, but the cause of its cause—its *remote* cause, as we say. In such cases, the task of explanation consists in interposing the links that connect the phenome-

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* Is this a true explanation? If it be, the column of mercury should not have a fixed height. If we take the barometer to the top of a mountain, the column should fall and its fall should be proportionate to the altitudes to which we ascend. This is found to be a fact. Here we have a confirmation of the explanation.

non with its so-called cause. 'Fire is applied to the powder with which a cannon is charged, there is a flash of light, a rush of air and a terrific noise, and at the same instant that our ears are almost split by the roar we see a large hole torn in an embankment a hundred yards away. This is a causal series. For the fire causes the powder to explode, the exploding in turn causes the flash, the roar, and the propulsion of the cannon ball, and the ball in its turn causes the rent in the earthworks.'* The rent is explained by mentioning the links in the chain that connect it with the application of fire. The links mentioned above do not give the whole story. How is it that the explosion almost splits our ears by the roar? How do we hear the noise? The explosion produces a violent disturbance in the air near the gun ; that disturbance is transmitted to the air adjoining it, and so on, till the commotion reaches the drum of our ear. Thence the disturbance is transmitted through the middle ear to the inner ear, and thence through the auditory nerve to a particular part of the brain. The disturbance in the brain is the immediate cause of the sound being heard.

A man whom we left quite sound in the morn-

* Yerkes : Introduction to Psychology, 314.

ing is found dead now. This is something strange ; and we seek an explanation of it. Suppose we are told that the man poisoned himself with arsenic. This is a sufficient explanation for practical purposes. But we may enquire how the use of a small dose of a particular substance has resulted in his death. That we call arsenic a poison simply means that we believe in its injurious, possibly fatal, effects on the human system. The action of arsenic is explained if we understand the changes that it produces in the system, in the stomach and the blood. An ordinary man feels no need of finding any link between the taking of arsenic and death ; but the physiologist and the doctor feel this need.

To an ordinary man such questions as the following appear almost unmeaning—Why do I *see* the *colour* of an orange, and *feel* its softness? Why do I not *hear* its *fragrance* and smell its *weight*? There is a limit beyond which we cannot go in our explanations, but our effort should be to go as far as we can. By interposing links between phenomena that are accepted as cause and effect, we secure that immediateness of sequence which, as we have seen, is the characteristic feature of causal connection scientifically considered.

CHAPTER XV

FALLACIES OF INDUCTION

1. Classification of fallacies.

Aristotle divides Fallacies into Verbal and non-Verbal. In the Verbal Fallacy, the defect lies in the language ; in the non-Verbal, it may be in the form of thought or in the matter of thought. In a formal Fallacy, a conclusion is illegitimately drawn from the premises, or the conclusion is irrelevant. In his list, Aristotle includes some fallacies that do not fall under Deduction. He had no Inductive Logic, but perceived that some of the common errors in reasoning are not syllogistic in character. Two alternatives were open to him—he might have ignored the non-syllogistic fallacies altogether or mentioned them though they did not quite fit into his system. He chose to be inconsistent rather than to be incomplete. *Non-causa Pro causa* or *post hoc ergo propter hoc* is a purely Inductive Fallacy.

Mill gives a comprehensive classification of Fallacies. He divides Fallacies into two classes

—Fallacies of Simple Inspection or Fallacies *A priori* and Fallacies of Inference. Fallacies of Inference are further sub-divided into two classes —(1) those in which evidence is not distinctly conceived (Fallacies of Confusion) and those in which it is distinctly conceived. Under Fallacies of Confusion are mentioned Fallacies of Ambiguity, *Petitio Principii* and *Ignoratio Elenchi*. Under the other sub-class are mentioned the Fallacies of Induction and Deduction. Inductive Fallacies are again distinguished as Fallacies of Observation and those of Generalisation.

All these may be set forth in the following table :—

Fallacies	Of Simple Inspection.		(1)
	Of Inference	Fallacies of Confusion.	(2)
		Deductive Fallacies.	(3)
		Inductive Fallacies—	
		(*i*) Of Observation.	(4)
		(*ii*) Of Generalisation.	(5)

Of these, Fallacies of Confusion and Deduction belong to Deductive Logic. Fallacies of Simple Inspection and Fallacies of Induction will be discussed here.

2. Fallacies of Simple Inspection.

Fallacies of Simple Inspection or *A priori* Fallacies are due to the fallacious tendencies of the human mind.

Strictly speaking, the discussion of these Fallacies does not belong to Inductive Logic ; but they do form a part of the errors that men commit in reasoning, and have been discussed by Logicians. 'Socrates,' says Bain, 'was the first person to urge strongly the natural corruption of the human intellect, and the need of a very severe remedial discipline, which in the shape of personal cross-examination, he was wont to apply to his fellow-Athenians. The theme was not again taken up in a vigorous manner, until Bacon composed the first book of the "Novum Organum." The elucidation of the inevitable miscarriages of the untutored understanding and the classification of *idola*—false lures, in that renowned work, instead of being laid to heart and followed up by fresh examples, became a matter of mere parrot repetition. The next person to treat the subject independently, and to go systematically over the ground was Mr. Mill in his chapter entitled 'Fallacies *A priori*.'*

3. Bacon's 'Idols.'

Bacon mentions four Idols or natural prejudices of the human mind. These are Idols of the Tribe, Idols of the Den, Idols of

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* Inductive Logic, 275.

the Market, and Idols of the Theatre. By Idols of the Tribe are meant the fallacious tendencies that are inherent in the nature of man—racial prejudices. Such a tendency is the habit of reading human desires into nature and personifying natural objects. We talk of the fury of the storm and of the beneficence of showers. This tendency is particularly strong in children and savages, but perhaps none of us is quite free from it.

The Idols of the Den are the prejudices that are peculiar to individuals ; they are derived from the particular den or cavern in which the individual lives—his disposition and education. We may be so prejudiced against certain individuals that we lose sight of good points in their character and over-emphasize their ordinary blemishes. Or we may be superstitious in certain matters, though we are able to take a sane view in the ordinary affairs of life. The Idols of the Market are the prejudices formed by the intercourse of man with man. Such an intercourse is carried on by means of language, and 'from a bad and unapt formation of words arises a wonderful obstruction to the mind. Words force the understanding, throw everything into confusion, and lead mankind into vain and innumerable controversies and fallacies.' Fallacies due to improper

use of language may be brought under this head.

The Idols of the Theatre are the prejudices that 'have crept into men's minds from the various dogmas of peculiar systems of philosophy.' For many centuries, the mind of Europe was under the spell of Aristotle's influence. At the present time, many of us are afraid of holding opinions that are believed to be rejected by 'Science.' Any institution that is undemocratic in character appears to us to stand self-condemned.

4. Mill's account of A priori Fallacies.

In speaking of the *A priori* Fallacies, Mill refers to the general assumption that the same order must obtain among the objects in nature which obtains among our ideas of them. If we always think of two things together, the two things must always exist together. And when we cannot conceive two things together, they cannot exist together. Mill adduces the following as examples of the superstitions that arise from this assumption :—

(i) 'Talk of the devil and he will appear,' has passed into a proverb.

(ii) The day on which any calamity has happened is considered an unfortunate day, and there is a feeling against transacting any important

business on that day; for on such a day our thoughts are likely to be of misfortune.

(iii) Among uneducated persons it is thought an unbecoming thing to talk of or suppose the death of any person while he is alive.

(iv) Another prejudice is that 'the conditions of a phenomenon must, or at least probably will, resemble the phenomenon itself.'

The lungs of a fox may be supposed to be a specific for asthma, because the fox is remarkable for its strong power of respiration. The brilliant yellow colour of turmeric indicates that it has the power of curing jaundice. We may suppose that the use of mutton will make a man a coward and the use of tiger's flesh will turn him into a hero.

Leaving these Fallacies, we may now pass on to a consideration of the Inductive Fallacies.

5. Fallacies of Observation.

Fallacies of Observation are of two kinds : Fallacies of Non-Observation and those of Mal-Observation. In a Fallacy of Non-Observation, the error consists in overlooking or neglecting facts, or some particulars about them which ought to have been observed. In Mal-Observation, something that is seen is seen wrong ; the phenomenon, instead of being recognised as it is, is mistaken for something else.

(i) Fallacies of Non-Observation.

'Non-Observation may either take place by overlooking instances, or by overlooking some of the circumstances of a given instance. If we were to conclude that a fortune-teller was a true prophet, from not adverting to the cases in which his predictions had been falsified by the events, this would be non-observation of instances; but if we overlooked or remained ignorant of the fact that in cases where the predictions had been fulfilled, he had been in collusion with some one who had given him the information on which they were grounded, this would be non-observation of circumstances.' (Mill.)

Examples of non-observation of instances will readily occur to the reader. Talk of dreams in a college class and some students must come forward to maintain that they are prophetic. On certain occasions they have turned to be true. These persons do not note the cases in which dreams have not proved prophetic. If they had noted them, they should have found that the agreement between a dream and subsequent actual fact is a rare phenomenon. Most of us know that sometimes men of subnormal intelligence succeed very well in life; and we generalise this experience and say that 'fortune favours fools.' Yes, it does favour them but more often it favours

only the wise man. A quack founds his reputation on the cases that he has cured ; the number of cases that he has not been able to cure is much larger, but it is not his interest to note these cases.

Why is it that we note only some cases and not others? A detailed discussion of this question belongs to Psychology ; here we may only mention the following points :—

(*i*) We have a natural tendency to notice affirmative and to neglect negative instances. 'This tendency,' says Fowler, 'is considerably intensified, if the affirmative instances are regarded as illustrations of some pre-conceived theory, or if the evidence afforded by them be supplemented by some powerful affection of the mind.' In dealing with Observation, we emphasised the point that Observation is essentially selective. We see what we wish to see. Fowler adduces the following illustrations : 'A man of a desponding temperament will dwell on the number of those who have failed, a man of sanguine temperament on the number of those who have succeeded in their respective professions. A man with strong sympathies will see only virtues or good traits of character, where one of a malevolent or critical disposition will see only vices or blemishes. An ardent adherent of a religious sect or political party will see nothing but good in those who agree

with him, nothing but evil in those who adopt a different creed or profess to be guided by different principles of policy.'*

(*ii*) Another tendency of the mind that explains some cases of Non-Observation is to acquiesce in the first instances which offer themselves, particularly if they are of a striking kind. A man goes to a foreign country. If his first experiences of the natives are unfavourable, very likely he will misjudge the whole people. A professor will find that his first impressions of his students stick to him, though they may not be fair representations of facts. Many people who see nothing interesting in birds will find on examination that their indifference is due to the unattractive character of the birds that came in their way in their childhood.

In Non-Observation of the other type, the defect lies not in the neglect of instances but in overlooking some essential aspects of them. As Voltaire said, incantations would put a whole flock of sheep to death if along with them you administer a sufficient quantity of arsenic. As an instance of this form of Non-Observation, Mill mentions cures by the sympathetic powder of Sir Kenlm Digby. He quotes the follow-

* Inductive Logic, 255.

ing passage from Dr. Paris (Pharmacologia, 23-24) :—

'Whenever any wound had been inflicted, this powder was applied to the weapon that had inflicted it, which was, moreover, covered with ointment, and dressed two or three times a day. The wound itself, in the meantime, was directed to be brought together, and carefully bound up with clean linen rags, but, *above all, to be let alone* for seven days, at the end of which period the bandages were removed, when the wound was generally found perfectly united. The triumph of the cure was decreed to the mysterious agency of the sympathetic powder which had been so assiduously applied to the weapon, whereas it is hardly necessary to observe that the promptness of the cure depended upon the total exclusion of air from the wound, and upon the sanative operations of nature not having received any disturbance from the officious interference of art. The result, beyond all doubt, furnished the first hint which led surgeons to the improved practice of healing wounds by what is technically called the *first intention*.'

(ii) Mal-Observation.

In Mal-Observation, what is seen is seen wrong. Our actual sense experience cannot be

challenged but in adult life this experience always blends with inference. Whenever we perceive anything, we infer half-consciously or unconsciously from sense experience. I may think that I see an orange on the table in front of me : really I only see its yellowness and rotundity. These are features of the orange, but they are not the whole thing about it. The orange is also soft and delicious and has a pleasant smell. These qualities also I have experienced in the past, and they have been associated in my past experience with the qualities that I now see. My perception of the orange is not simply a sensation of yellowness and rotundity, but an experience in which sense impressions mingle with inference.

Now, there can be no mistake about sense experience ; if I see yellowness, I do see it. But the thing on the table may not be an orange ; it may be a toy made of clay. If it is, I have a wrong perception or illusion. In Mal-Observation, the error is due to misinterpretation of sense experience. People ridiculed the Copernican system because, said they, they *saw* the sun rise and set, and the stars revolve in circles round the pole. Really, they saw nothing of the kind. What they actually saw was a phenomenon that could be reconciled with their view as well as with a view totally different from it.

Sometimes our impression is not due to any external stimulation. We project our own image and objectify it. We seem to hear voices, when no sound is made near us ; we see things that are nowhere to be found in our field of vision. These experiences are known as hallucinations. A persistent hallucination is called a delusion. When a man begins to have delusions, he should put himself under medical treatment ; otherwise, compulsory, though free, treatment would be provided for him.

6. Fallacies of Generalisation.

In the fallacies of Generalisation, error is committed in respect of the Inductive Process itself. This may be done in two ways. We may over-rate the value of the evidence, or misunderstand the nature of the causal connection. In the former case, we rely on Simple Enumeration or Analogy and erroneously suppose that a causal connection has been established. In the latter, *a* and *b* are found to be causally connected, but the nature of this connection is not rightly understood. We shall now examine these fallacies one by one.

(i) Fallacies of Simple Enumeration.

As we have seen in a previous chapter, all

that Simple Enumeration can give us is an Empirical Generalisation. We can say that so far as we have observed, a particular relation is found to exist between certain phenomena. This may be only a causal conjunction. In Simple Enumeration, there is no analysis of the phenomena, no comparison of the instances, and, therefore, no separation of the material circumstances from their immaterial concomitants. What is found true within certain limits of space and time may not be true beyond these limits. We observe a certain order on our earth. If we maintain that the same order exists in remote parts of the universe, we commit a fallacy. Again, it is illegitimate to infer that men's dispositions and desires always were or will always be as they are now. Common-sense acquiesces in the formula 'whatever has never been, will never be.' And yet there is no justification for this inference. Mill gives the following illustrations :—

'Negroes have never been as civilised as whites sometimes are, therefore, it is impossible they should be so. Women, as a class, are supposed not to have hitherto been equal in intellect to men, therefore, they are necessarily inferior. Society cannot prosper without this or the other institution ; e.g., in Aristotle's time, without slavery ; in later times without

an established priesthood, without artificial distinctions of rank, &c. One poor persan in a thousand educated, while the nine hundred and ninety-nine remain uneducated, has usually aimed at raising himself, out of his class, therefore education makes people dissatisfied with the condition of a labourer. Bookish men, taken from speculative pursuits and set to work on something they know nothing about, have generally been found or thought to do it ill; therefore philosophers are unfit for business.'*

If 500 men in a million have for some years past died of snake bite, it would be rash to infer that this number must die in this way in future also. There is a definite cause of the effect in question and it is possible to counteract it. The number of deaths by snake bite will be nearly this, if the causes and conditions remain approximately what they are now. It is not necessary, however, that this should be so. A friend of the writer passed his 33rd year in constant dread, because three of his relatives had died at the age of 33.

(ii) False Analogy.

This fallacy may occur in two ways. Some-

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* Logic, V. v. 4.

times it consists in employing the analogical argument correctly but over-rating its probative force. We know, for instance, that the planets resemble the earth in being almost spherical in form, revolving round the sun in elliptical orbits, in revolving round their axes and in their chemical composition. Do they resemble the earth also in sustaining animal or human life? There is some resemblance between them and the earth, but that is not enough to convince us that they are inhabited. All that we can affirm is that the likelihood of their being inhabited is greater than it would be, if they did not resemble the earth in these points. Secondly we may have a false analogy, where resemblance in one point is inferred from resemblance in another point, though there is not only no evidence to connect the point by way of causation, but the evidence tends positively to disconnect them. A few illustrations will make the point clear. It is sometimes argued that just as in a family paternal government is the best, so in a state, despotic rule will work well. Even if a paternal government is in all cases the best in a house, its excellence does not rest on the irresponsibility of the head of the family. Those who support despotism on the basis of this analogy forget that a father has natural affections for his children and is as a rule the wisest member of the

family. A political despot does not possess this affection for his subjects and may not be wiser than they are.

In discussing the character of the analogical argument, we referred to the analogy between an individual and a society—an analogy on the basis of which it is affirmed by some that the period of youth in a body politic must be followed by old age and finally by death. There we quoted Mill's opinion that when bodies politic die, it is of disease or violent death ; they have no old age. On this illusion, Lewis remarks :—'Both a man and a community, indeed, advance from small beginnings to a state of maturity ; but a man has an allotted term of life, and a culminating point from which he descends ; whereas a community has no limited course to run ; it has no necessary period of decline and decay, similar to the old age of man; its national existence does not necessarily cease within a certain time......A political community is renewed by the perpetual succession of its members ; new births, immigrations, and new adoptions of citizens keep the political body in a state of continuous youth. No such process as this takes place in an individual man. If he loses a limb, it is not replaced by a fresh growth.'*

* Quoted in Fowler : Inductive Logic, 333.

(iii) Misinterpretation of the nature of the causal relation.

The aim of Inductive Methods is to establish a causal connection between two phenomena—*a* and *b*. Sometimes we believe they are causaly connected, when , in fact, there is no connection between them. What is simply an antecedent is taken to be a cause. This is the fallacy known as *post hoc ergo propter hoc* in the traditional Logic. The appearance of comets was for a long time supposed to be connected with wars. Seeing a cat when we set out on a journey is regarded as ominous. Many of the popular superstitions are illustrations of this fallacy. Where the phenomena are causally connected we may fall into error about the nature of the connection. We may mistake *a* for the cause of *b*, when in fact (i) *b* is the cause of *a*, or (ii) the connection between them is reciprocal, i.e., *a* produces *b* and *b* produces *a*, or (iii) *a* and *b* are both joint effects of *c*, or (iv) when *a* is but a part of the cause of *b*.

Examples of these fallacies can be easily found. I may suppose that my headache is the cause of sleeplessness, whereas, in fact, sleeplessness may be the cause of the headache, or both may be due to fever. A man feels interested in philosophy because he devotes the best part of his time to its study, and he does it because he feels

interested in the study. Dissolute life is the cause of physical deterioration, and, on the other hand, a man with a weak constitution most easily succumbs to temptation. A man's success or failure in business may be due to a number of causes, and he may erroneously ascribe it to one of the conditions, ignoring others which are equally essential to the production of the effect. A man who fails in an examination finds it hard to take note of all the circumstances that co-operate to prolong his stay at college. It is more convenient to suppose that the failure is due to 'stiff marking,' or headache during the examination hours. Some students may regret that the present chapter closes with such an illustration. If they do, they will find here another instance of the Fallacy of Simple Inspection.

APPENDIX A

ANALYSIS OF ARGUMENTS

An important aim of the study of Logic is to enable the student to analyse arguments and to test their validity. Much depends upon the method adopted to handle arguments. Our first aim should be to find the conclusion that the argument seeks to establish. This is generally given at the beginning or the end of the passage. We should next proceed to note the evidence that is produced to establish the conclusion. The methods employed will not now be difficult to find. The last step is to test the validity of the arguments. In many arguments we have Deductive and Inductive reasoning combined. A few examples, inductive in character, are analysed below to serve as models.—

(1) "We may conjecture the inhabitants of the sun are like to the nature of that planet, more clear and bright, more intellectual than those in the moon where they are nearer to the nature of that duller planet, and those of the earth being more gross and material than either, so that these intellectual natures in the sun are more form than matter, those in the earth more matter than form, and those in the moon betwixt both. This we may guess from the fiery influence of the sun, the watery and aerous influence of the moon, so also the material heaviness of the earth. In some such manner likewise is it with the regions of the other stars; for

we conjecture that none of them are without inhabitants, but that there are so many particular worlds and parts of this one universe as there are stars, which are innumerable, unless it be to Him who created all things in number."

(Quoted by Fowler from Wilkin's 'Discovery of a new world in the moon.')

The author seeks to maintain the thesis that the intelligence of the inhabitants of a planet or star depends on the material of the planet or star on which they live. The argument, if it can be so called, is based on a number of assumptions. It is assumed in the first place that the sun, the moon and the stars are all inhabited. Secondly, the constitution of these bodies is assumed without any evidence. Thirdly, there is the assumption that the material of which a heavenly body is made has a connection with the intelligence of the inhabitants living on it. An inductive argument should be based on accurate observation and should be a valid generalisation. In the present case, there is no observation worth the name and no valid generalisation.

(2) " Certain white mice in Russia—unlike human beings—are being trained to expect dinner when an electric bell rings. For this purpose, Professor I. V. Pavlov, in his Petrograd laboratory, has employed five generations of mice. " With the first," according to the 'British Medical Journal,' " it was necessary to repeat the combination of ringing the bell and feeding 300 times in order to form a well-established reflex. The next generation formed the same reflex after 100 repetitions. The third generation acquired this reflex after 30 repetitions, the fourth after 10, and the fifth after five only. The Professor anticipates that one of

the next generations of mice would show the food reaction on hearing the sound of the electric bell for the first time."

At the first glance the argument seems to prove that white mice are capable of being trained for a certain purpose, *viz.*, to expect food when an electric bell rings. A number of observations show that white mice do possess such capacity. They are fed a number of times when an electric bell is also rung. In consequence an association is formed between the ringing of the bell and getting food and the sound of the bell produces an expectation of food. Thus regarded the argument employs the method of simple enumeration. A closer examination of the argument, however, will show that (1) experiments are not performed on any mice indiscriminately and (2) the results obtained do not simply show that an association between the ringing of the bell and expectation of food can be formed. Experiments were performed on five generations of mice and the time required for the association being formed went on decreasing. The real object of the experiments was to see whether this ability when acquired could be transmitted to the offspring. The mice on which the experiment was originally performed required 300 repetitions, those of the second generation 100, those of the third 30 and so on. This shows that as the influence of heredity increased in strength, the time required for the association decreased. Here we see an employment of the Method of Concomitant Variations. We further see that the decrease in time is practically at a uniform rate; each generation at the earlier stages requires $\frac{1}{3}$ or about $\frac{1}{3}$ of the time that the preceding generation required. The argument is a good instance of the application of the Method of Concomitant Variations and

shows that a particular acquired character is transmitted by heredity.

(3) "From childhood upwards we have all been taught to believe in the blessings of pure air. Is it really essential to the preservation of life and health? That is a point as to which physical science has not yet said its final word, but the present tendency is to answer the question in the negative. Experiments on school-children appear to justify the conclusion that under certain conditions children may inhale impure air not only without injury to themselves, but with relatively beneficial effect as compared with pure air breathed under different conditions. Two groups of children were selected. One group was taken into a room in which the air was kept perfectly pure but without perceptible motion. The other occupied a room the atmosphere of which had been elaborately befouled but was stirred and circulated by means of fans. Tests taken after the expiry of some hours showed that in respect of mental alertness, pulse, temperature, and general health, the children confined in the contaminated air were in altogether better condition than the others. The inference is that purity is a less essential quality of the air we breathe than movement. Stagnation is as baneful in the atmosphere as in the duck pond, and it seems to follow that the refreshing effects of the fan or the Punkah in the tropics are due as much to the motion of the air as to the coolness imparted."

The aim of the argument is to prove that (1) movement is essential in the air we breathe, and (2) movement is more valuable than purity itself. The value of movement of air for human life and health could be established by comparing the effects on the human sys-

tem of pure air in motion with those of pure air without motion, or the effects of impure air in motion with those of impure air without motion. The conclusion becomes all the more strong if we compare the effects of impure air in motion with those of pure stagnant air. The result of observation on school-children is stated to be that in respect of mental alertness, pulse, temperature and general health, impure air in motion is more valuable. There is no question as to the value of purity of air for human life and health. The argument shows that valuable as purity is, movement of air is still more valuable. The method employed is the Method of Difference. Pure air is more invigorating than impure air. This is a matter of common experience. If we add motion to the impure air, not only does it cease to be depressing, but it becomes actually more invigorating than pure air which is not in motion.

(4) "In the United States for 20 years there has been a continuous intensive effort to combat tuberculosis. Since the adoption of Prohibition the rate of decline in the death rate from tuberculosis has been immensely augmented. Here are figures taken from the Bulletin of the St. Louis Health Department:—

Year.	Tuberculosis Death Rate per 1,00,000.	Per cent of increase or decrease from rate in 1911.
1911	203·6	...
1912	199·1	2·2 —
1913	203·9	0·01 +
1914	208·2	2·0 +
1915	195·7	3·0 —
1916	196·7	3·0 —
1917	213·9	5·0 +
1918 (Influenza year)	190·1	6·0 —
1919 (6 mos. Prohibition)	145·7	28·0 —
1920 (Prohibition)	129·3	36·0 —
1921 (Prohibition)	111·9	45·0 —

From the figures it appears that three of the ten years, 1913, 1914 and 1917, showed an increase of deaths from tuberculosis over 1911, and four other years, 1912, 1915, 1916 and 1918 a very slight decrease. In 1919, the percentage of decrease jumped to two figures and continued to increase during the following two years. This remarkable improvement beginning suddenly in 1919, and continuing through 1921, would indicate the entrance of some new and decisive factor operating for the arrest of tuberculosis.

No suggestion is made by the health authorities of any new factor entering the situation except Prohibition which was operative during one-half of the year 1919 when the decrease went from 6 per cent to 28 per cent and during the whole of the years 1920 and 1921 when it mounted to 36 per cent and 45 per cent respectively."

The writer of the passage tries to prove that Prohibition (of manufacture and use of intoxicating liquors) is responsible for the remarkable decrease in the death rate from tuberculosis in St. Louis during 1919—21. Observation extending over ten years shows that the death rate from tuberculosis for seven years before the introduction of Prohibition varied within narrow limits. This shows that conditions affecting tuberculosis were practically uniform. And even the slight variation that there was, was not in one direction. For not more than two consecutive years could continuous increase or decrease be observed. In 1919, a remarkable change appeared and it continued in the same direction during two succeeding years. This change can be accounted for by a new factor that was introduced in 1919, and continued to operate in 1920 and 1921. No factor other than Prohibition, which could be regarded as adequate

to the production of the effect, is mentioned. It is probable that Prohibition is the cause of reduction in the death rate from tuberculosis. (Method of Difference.) There is one circumstance that strengthens this view. In 1919, Prohibition was in force for six months only. We could expect that the results would be better in 1920 than in 1919. This is actually the case. Then in spite of the Prohibition, some illicit manufacture and secret use of liquors may have continued in 1920. Prohibition was probably more effectual in 1921 than in 1920, and we find a greater decrease in the death-rate in 1921. (Method of Concomitant Variations.)

We may also mention that our general knowledge of the connection between vitality and tuberculosis on the one hand and vitality and use of liquors on the other, supports the thesis. The argument is fairly strong; the only weak point in it is that we are not quite sure that there was no other potent factor introduced in 1919. No suggestion is made by the health department that there was such a factor. If this can be taken to mean that the health department denies the existence of such a factor, the connection between Prohibition and reduction in the death-rate from tuberculosis may be said to be established.

APPENDIX B

EXAMINATION PAPERS

(*The student reader is strongly advised to write out answers to the questions that follow. His answers will show him, as nothing else can, whether he has mastered the contents of the book.*)

I

PUNJAB UNIVERSITY.

1915

1. (*a*) What do you understand by Generalization?

(*b*) Show how Induction performs a function which is beyond the scope of Deduction.

(*c*) Show also how the two processes interact.

2. (*a*) How do you suppose the conception of *Causation* arises in our minds?

(*b*) Define *Cause* and *Effect*.

(*c*) What is meant by saying that 'cause and effect are equal in amount of energy?'

3. (*a*) Why are Observation and Experiment a part of Logical Method?

(*b*) Distinguish between Simple Observation and Experiment.

(*c*) What are the chief sources of error in the course of these processes?

4. (*a*) Define Hypothesis, and give examples.

(*b*) What process must precede the formation of a hypothesis?

(*c*) What is required to fully verify and establish a hypothesis?

(*d*) What is a *Theory*? a *Law*?

5. Explain Argument by Analogy.

Give an example and estimate the value of this kind of argument.

6. (*a*) Mention some experiments which would illustrate the "Method of Difference."

(*b*) What principles underlie all methods of Direct Inquiry?

(*c*) Criticize this argument: "Opium cannot be injurious, for I have just read in the papers of the death of a confirmed opium-eater at the ripe age of 95 years."

7. (*a*) By what method of reasoning would you conclude that a case of indigestion was due to a dish of cucumbers eaten the previous night?

(*b*) What fallacy if the farmers explain a poor crop by a recent change in the Government?

(*c*) Can you point out the fallacy in any of the common proverbs or superstitions about "good luck" or "bad luck"?

1916

1. (*a*) Distinguish between Inductive and Deductive Logic.

(*b*) What is the meaning of the distinction between a Perfect Induction and an Imperfect Induction?

(*c*) How certain can you be that the conclusion of an Induction is true?

(*d*) Is Classification an Inductive or a Deductive process?

2. (*a*) Give examples of any two of the Methods of Induction.

(*b*) Name the Method, and formulate the *Canon* or rule.

3. (*a*) Why do the Sciences use the Inductive Method?

(*b*) Do they use Deduction also?

(*c*) What is the use of Scientific Laboratories?

4. (*a*) What is meant by the Uniformity of Nature?

(*b*) Why should we *think* it uniform?

(*c*) Can we *prove* it to be so?

5. (*a*) What is meant by *explaining* a thing?

(*b*) Show that there are various degrees of Explanation.

6. (*a*) Why is Testimony often so unreliable?

(*b*) Show how Assurance Companies make use of Induction in determining the *Probable Number of years* a man of a certain age may still expect to live.

7. (*a*) Name and illustrate several Fallacies common to Induction.

(*b*) Criticize the following statement:—"You brought a curse upon my house, for no sooner had you left it than the lightning struck my roof."

8. (*a*) Is it logical to say, "John Smith must be a good student, for his brother won a mathematics prize?"

(*b*) With the following combinations of antecedents and consequents, find the cause of x : B D L O—qxrs., B D O—qrs.

What is the method?

9. Define

(*a*) Phenomenon

(*b*) Antecedent

(*c*) Analogy

(*d*) Experiment

(*e*) Law

1917

1. Discuss the inter-relation between Induction and Deduction and illustrate by a series of examples.

2. (*a*) Distinguish between *Experience* and *Experiment*.

(*b*) What is the purpose of Experiment?

(*c*) How is an Hypothesis to be verified?

3. (*a*) Lay down a set of rules for correct Observation and Experiment.

(*b*) Mention several sciences in which one or the other of these processes preponderates, or in which they are both equally employed.

4. With reference to the Methods of Induction—

(*a*) Discuss the comparative certainty of their results.

(*b*) May both Observation and Experiment be employed in the application of each of these methods?

5. (*a*) What fallacies arise from the careless use of language?

(*b*) What fallacies from the careless observation of facts?

6. (*a*) Criticize the statement : "I said in my haste that all men are liars."

(*b*) Construct an Hypothesis to explain some fact in your own experience, and explain how it may be verified or overthrown.

(*c*) Construct an argument to show the harm or the benefit of some habit, and analyse your reasoning, showing the methods which you have employed.

7. Given the following sets of antecedents and consequents, what conclusion can you draw, and on what grounds?

X Y W U	... ...	h g j k
Y Z W	... ...	j h i
Y P Q	... ...	a j f
X W U	... ...	g h k

Y R O ... ... a j d
X Y P Q ... ... k j f e
X Y U ... ... k j g

8. Discuss or explain briefly:—

(*a*) Fact;
(*b*) Axiom;
(*c*) Crucial Instance;
(*d*) Causes;
(*e*) Plurality of Causes.

1918

1. Discuss the nature, method, and value of *Classification*.

2. (*a*) Analyse the conception of the *Uniformity of Nature*.

(*b*) Enumerate and characterise its forms.

3. What is the difference between the *Laws of Nature*, and the Laws of the Land?

Give examples of the Laws of Nature, and explain how they are discovered.

Are they forces?

4. Discuss the method of *Concomitant Variations*, giving an example.

What is the comparative value of this method, and the special sphere of its usefulness?

Why is this method called "a method of *Quantitative Induction*"?

5. Enumerate and exemplify "the Idols."

6. Criticise and estimate the following statements, and if they are fallacious, indicate where their weakness lies :—

(*a*) "Father, *why* does the tiger have sharp claws?" "My child, it is *because* it belongs to the cat family."

(*b*) If the Holy Man shall curse you, you will surely meet calamity before the month has passed.

(*c*) It is nobody's concern if I drink, and beat my wife; for a man may do what he will with his own.

7. For the following sets of *consequents* construct an appropriate series of *antecedents*, and indicate the principles that the completed example illustrates :—

. . . . b c e a
. . . . b d f q r s y
. . . . c d f r y a
. . . . b d g q s w y
. . . . e f g r w
. . . . b e g q w

8. Write *brief* explanatory notes upon the following :—

(*a*) Perfect Induction,

(*b*) False Analogy,

(*c*) Intermixture of Effects,

(*d*) Verification of Hypothesis,

(*e*) Value of Testimony.

1920 and 1921

1. What is Experience? Discuss the relation between Observation and Experiment. What methods of Induction employ one or the other of these in a special degree?

2. What is Law? Distinguish various kinds of Laws. What are the stages in the process of establishing a Law of Nature?

3. Distinguish between Discovery and Proof as the ultimate object of Induction. What is the real meaning of Explanation?

4. Formulate carefully the assumptions on which scientific Induction rests, and bring forward any evidence you can in support of these assumptions.

5. What is meant by a Law of Probability? How can these Laws be reconciled with the Laws of the Uniformity of Nature and of Necessary Causation?

6. Explain what is meant by the Uniformity of Nature and show how Induction is related to this Postulate.

7. Define hypothesis. What conditions should a hypothesis satisfy in order to be validated?

8. Describe the method of Difference and the method of Concomitant Variations, and formulate the canon of each.

9. Define the notion of cause and explain in what sense, if any, cause and effect are reciprocal.

II

INTERMEDIATE BOARD, U.P.

1922

1. Explain what is meant by the Principle of Causation, and show how it is related to Inductive reasoning.

2. Distinguish between, and with the aid of examples display the characteristics of the following:—

Municipal Laws, Laws of Nature, Empirical Laws, Ultimate Laws.

3. How are Observation and Experiment related? Discuss their relative difficulty and importance.

4. Explain and illustrate each of the following: (*a*) perfect induction; (*b*) crucial instance; (*c*) argument from Analogy.

5. A certain school had 150 pupils on its roll. One morning the attendance suddenly fell to 50. The average attendance had been 130, the remaining 20 being accounted for by slight ailments, social engagements, and indifference. There was no epidemic or mela in the neighbourhood to account for the sudden drop. There had been, however, a number of political meetings in the town recently. So the Head Master concluded that this fact accounted for the unusual number of absentees.

By which of Mill's Methods was this conclusion reached?

From the example given show the characteristics and the defects of this method.

6. How would you proceed, by experiment or observation, to prove (or disprove) the belief that the stars have an influence on a man's life?

(*N.B*—The candidate may prove or disprove as he prefers.)

7. Distinguish between Natural and Artificial Classification. What is the value of each in Logic?

8. Analyse, state the nature of the argument, and criticise the reasoning in any *three* of the following:—

(*a*) Stories are frequently heard of a wonderful feat performed by Indian jugglers. It is claimed that a rope thrown into the air retains its upright position. A boy then climbs the rope and disappears. Many years ago a learned society in Madras gave wide publicity to an offer of Rs. 500 to any one who could do the trick or prove that it had ever been done. As no one claimed the reward, the society took it as proved that the stories were false.

(*b*) In a mining town in the Western States of America the boast was made that, except through accident or foul play, there had been no deaths in the past three years. It was claimed, therefore, that the town was exceptionally healthy.

(*c*) Persons coming into a district in which malarial fever is prevalent usually remain free from malaria, if they protect themselves from mosquito-bite, while a large percentage of those who carelessly expose themselves to mosquito-bite contract malaria. Moreover in marshy districts in which malaria has been prevalent, malaria disappears in proportion as the water is drained away: and the mosquito can only breed in water.

(*d*) Several of my friends who passed the School Leaving Certificate Examination in the second division have passed the Intermediate Examination in the second division. Therefore I hope to pass the Intermediate Examination in the first division, having passed the

School Leaving Certificate Examination in the first division.

(*e*) It has been observed that as education spreads the number of crimes becomes less. People therefore advocate universal compulsory education on the ground that thus crime will disappear. But yet we see that many criminals belong to the educated classes, and that the majority of uneducated persons are not criminals.

1923

1. Distinguish carefully between Deduction and Induction. Show how they are related to each other.

2. State and explain briefly the postulates of Inductive Inference.

3. What do you understand by Observation and Experiment? Name and explain by examples some of the important errors incident to Observation.

4. (*a*) Explain the conditions of a valid hypothesis.

(*b*) Give, with examples, the meaning of (i) A Working Hypothesis, (ii) An Established Hypothesis and (iii) A Crucial Instance.

5. "If after much observation of *B*, we find that it agrees with *A* in nine out of ten of its known properties, we may conclude with a probability of nine to one that it will possess any given derivative property of *A*."—*Mill.*

"The force of an argument from Analogy depends upon the character of the identity, and not upon the apparent amount of similarity."—*Welton.*

Discuss the comparative validity of the above statements giving suitable examples.

6. Discuss the value of Mill's method of agreement, and consider how far it is affected by the "plurality of causes" and "intermixture of effects."

7. State and explain briefly the nature, the conditions and the value of Scientific Classification. How does Classification differ from Division?

8. Test the validity of the following arguments, and indicate the nature of the fallacy, if there is any:—

(i) We daily see with our own eyes that the sun rises in the morning, travels across the sky, and sets in the evening; while our own planet remains stationary. Therefore, it is certainly wrong to say that the earth moves round the sun.

(ii) The heavy failure in the Intermediate Examination of the present year must be due to an increase in the number of Intermediate Colleges, for during the previous years, when the new colleges had not come into existence, the results were not so bad.

(iii) Ramachandra's friend must have died of influenza, for that is the most common disease of the present season.

(iv) Joseph's son must be very intelligent, for he behaves exactly like one of my own students, who, I know, is an exceptionally bright boy.

(v) It has been found that the number of criminals who can read and write is much larger than the number of those who cannot. It cannot, therefore, be maintained that education tends to diminish crime.

1924

1. What do you understand by the Law of Causation and the Uniformity of Nature? How are the two related?

2. What is a Hypothesis? Give some account of different kinds of hypotheses.

3. What are the conditions of a good argument from Analogy?

4. How are observation and experiment related to each other? Bring out their importance in Induction.

5. Several large towns in the north of England are engaged in textile (cotton and woollen goods, for example) manufacture and in these same towns infant mortality is very high. *A*, *B*, *C*, and *D*, are textile manufacturing towns and must therefore have high infantile mortality.

What kind of argument is this, and what deductive fallacy would be committed if the universal conclusion "All textile manufacturing towns have high infant mortality" were drawn from the facts given above?

6. "Induction is the process of inference from particular to particular, while Deduction is inference from general to particular." Discuss this statement and explain what you consider to be the relation between Induction and Deduction.

7. Discuss briefly Mill's "Inductive Methods," and distinguish the "methods of observation" from the "methods of experimentation." Illustrate your answer by means of examples.

8. Explain fully what logical methods would be of greatest value in determining—

(1) The cause of plague.

(2) The effects of the retail sale of intoxicating liquor.

(3) The prosperity or decline of a College.

9. Analyse any *three* of the following arguments, discussing their validity, and indicating the method used :—

(*a*) The principal cause of the awakening in the country is the spread of Western ideas through the Western system of education. The awakening is more conspicuous in British India than it is in the Native State; and in British India itself provinces that have imbibed the spirit of Western education more are more progressive than others. Looking to the development of political consciousness in the country as a whole, we find it has run parallel to the development of Western education.

(*b*) Do games influence the character of young men? The Principal of a College insisted that every student must spend some time every day in the playground. In the course of a few months a distinct change in the tone of the College was observed. The students were more manly, straightforward, and honest than before. The Principal left the College and was succeeded by another who had more faith in reading books. Not long after any one could see that, though the students of the College did better in the examinations, they had distinctly deteriorated in character.

(*c*) On a board where a number of ants were wandering about, I put some small pieces of wood, and

on these pieces of wood I put some honey. I then put some ants to the honey and imprisoned them. While these ants were imprisoned very few ants came to the honey. But after the imprisoned ants were released, within three-quarters of an hour 54 ants came. The conclusion seems to be that ants can communicate with each other.

(*d*) A community consists of individuals, and individual consists of cells. Both of them are complex structures. The individual grows and so does the community. The community thrives when members co-operate with one another, and the health of the individual is dependent on the organs working in harmony. There being such close resemblance between the individual and the community, it is obvious that the community, like the individual, is mortal.

(*e*) In India it has been noticed that as soon as the hot weather begins epidemics often take place and we have either cholera or small-pox or fever. It is clear therefore that the hot weather brings disease; but it is also true that plague is worst during the cold weather. Are we to say, therefore, that cold also causes an epidemic?

1925

1. Distinguish the various senses in which the word Induction has been used. Explain clearly the nature of Scientific Induction.

2. Explain fully the difference between the Law of Causation in Induction, and the Laws of Causation discovered by Science.

3. What is Hypothesis? Bring out its importance in Induction. How does it differ from Theory? Illustrate your answer by examples.

4. Compare Observation and Experiment as means of gaining data for Reasoning.

5. Show how the method of agreement differs from simple enumeration. Is the latter of any scientific value at all? What are the main defects of the method of agreement?

6. Show by an application of Mill's methods that the education of the masses is essential to the progress of a nation.

7. What is the argument from analogy? How does it differ from Induction? How could you estimate the value of an analogical argument?

8. How are Induction and Deduction related? Discuss this fully after carefully defining Induction and Deduction.

9. Analyse any *three* of the following arguments and discuss their validity, pointing out fallacies, if any.

(*a*) We should think it a sin and shame if a great steamer, dashing across the ocean, were not brought to a stop at a signal of distress from a small boat. And yet a miner is buried alive, a workman falls from a scaffold, a brakeman is crushed in coupling Railway carriages, a merchant falls ill and dies and society leaves widow and child to bitter want or degrading alms.

(*b*) It is said that a large number of babies die in India either at birth or within the first two years after birth and a large number of mothers also die in giving birth to children. These deaths are said to be due to ignorance of rules of sanitation and neglect of modern

medical science. But this cannot be true as there are millions of babies and mothers who are alive and so after all modern medicine and surgery are not necessary to prevent the deaths of babies and mothers.

(*c*) The prices of food-stuffs have gone up enormously during the last twenty years. It is within the memory of some people that 'ghee' at one time was sold 5 seers to the rupee, and only a few years back wheat could be had at the rate of 40 seers to the rupee. During this time the area of land under irrigation has greatly increased and Railways have been built. The cause of India's poverty must therefore be increased agriculture and the Railway system of the country.

(*d*) The people living in cold countries generally possess a good physique; for Englishmen and Afghans who come to India are generally tall and well-built. On the other hand, people living in hot climates are weak and short. But there are many hill tribes who are short of stature and not strong. Has climate anything to do with the growth of the body?

(*e*) People who do not go to school generally have good eye-sight. Among students those reading in colleges suffer from short-sightedness more than school-boys: and even college students have better sight than their Professors. Education is the cause of weak eye-sight.

1926

1. "Opium is poisonous;

The substance in my hand is opium;
Therefore, the substance in my hand is poisonous."

Explain the nature of the logical process underlying (i) your belief in the major premise, (ii) your belief in the minor premise, and (iii) your belief in the conclusion.

2. What is Classification? How does it differ from formal Division? What are the requisites of a Natural Classification?

3. Explain and examine in detail the following statement:—

> 'A cause is the immediate, invariable, unconditional antecedent of a phenomenon.'

4. What is meant by 'varying the circumstances' in scientific investigation? What is the use of the process? Add illustrations to explain your meaning.

5. State and illustrate with examples (symbolic and concrete) the Method of Concomitant Variations. What are the circumstances in which it is specially applicable?

6. Explain and illustrate any *three* of the following:—

(i) Working Hypothesis.

(ii) Plurality of Causes.

(iii) Mutuality of Cause and Effect.

(iv) Colligation of Parts.

(v) Mal-Observation.

7. What is meant by Scientific Explanation? Describe the various forms it assumes.

8. Attempt an explanation of *one* of the following facts :—

(*a*) The census of 1921 showed that whereas Allahabad, Benares, and Lucknow had lost in population during the preceding ten years, Cawnpore had considerably gained during the same period.

(*b*) At the Intermediate Examination of 1925, the percentage of passes was as follows :—

Boys, 46 per cent

Girls, 85 per cent

What logical methods do you employ in your explanation?

9. Analyse any *three* of the following arguments, and discuss their validity, pointing out fallacies, if any :—

(*a*) The establishment of new Universities in recent years has greatly advanced the cause of higher education in India. The percentage of passes in some of them is very high—about 90 or 95. In one of them, not only did all the students in a post-graduate class pass the examination, but everyone of them did also obtaining a first class. The older Universities cannot keep pace with the new Universities. Everywhere, old age means exhaustion and inefficiency.

(*b*) Nobody can be healthy without *exercise*, neither Natural Body nor Body Politic; and certainly, to a Kingdom or State, a just and honourable war is the true *exercise*. A civil war, indeed, is like the heat of a fever, but a foreign war is like the heat of *exercise*, and serves to keep the Body in health.

(*c*) The number of qualified medical men has considerably risen during the last ten or fifteen years. In large towns, one finds dispensaries and hospitals on all sides. But has all this resulted in any improvement in the health of the people? The number of in-door and out-door patients has been steadily rising. Medical men and medical halls have tended to increase disease rather than decrease it.

(*d*) Who pays for the advertisements—the seller or the buyer? Neither; the advertisements pay for themselves. The more you advertise your goods, the more you sell. Increase in production means lowering the cost of production, and the saving thus effected will suffice to pay for the advertisements.

(*e*) It is sometimes affirmed that the prosperity of a country depends upon its industrial development. This cannot be true, because no country can start industries unless it has got a large amount of capital to invest in the industries.

(N.B.—*In case of each of the arguments selected, state clearly* (*a*) *the conclusion suggested*, (*b*) *the evidence produced*, (*c*) *the method employed, and say* (*d*) *whether the conclusion is validly drawn*.)

1927

1. Define Induction, and describe its aim. Explain the remark:—

> 'Deduction and Induction are continuous operations.'

2. Distinguish between Observation and Experiment. In what respects is Experiment superior to Observation? Has Observation any advantage over Experiment?

3. Write explanatory notes on the following:—

(i) Uniformity of Co-existence.

(ii) Intermixture of Effects.

(iii) Counteracting Causes.

Add examples.

4. Explain clearly the nature of argument from Analogy.

How would you distinguish between a sound and an unsound Analogy?

5. How would you proceed to prove or disprove the following statement? Indicate clearly the method or methods employed in your argument:—

The introduction of Constitutional Reforms has been the cause of communal dissensions in India.

6. State the canon of the Joint Method, and illustrate its use.

Discuss the logical value of this Method.

7. What is Hypothesis? What is its value in scientific investigation?

Describe the conditions of a legitimate hypothesis.

8. Explain and examine the following statement:—

'All Methods of Induction are merely Weapons of Elimination.'

9. Analyse any *three* of the following arguments, and discuss their validity, pointing out fallacies, if any:—

(*a*) All cities have theatres; and the more theatres a city has, the more prosperous it is. Look at Calcutta,

Bombay, and Lucknow. Therefore, theatres are the cause of the prosperity of cities.

(*b*) War is a blessing, not an evil. Show me a nation that has ever become great without bloodletting.

(*c*) I am a Jew. Hath not a Jew eyes? hath not a Jew hands, organs, dimensions, senses, affections, passions? fed with the same food, hurt with the same weapons, subject to the same diseases, healed by the same means, as a Christian is? If you prick us, do we not bleed? if you tickle us, do we not laugh? if you poison us, do we not die? and if you wrong us, shall we not revenge? If we are like you in the rest, we will resemble you in that.

(*d*) The number of students attacked by malaria in a College Hostel in a certain year was as follows:—

Ground-floor:	10 per cent.
First-floor:	8 per cent.
Second-floor:	6 per cent.

It is clear from this that breathing pure air is a protection against malaria.

(*e*) Plants that grow in light develop green colour in their leaves; plants that grow in the dark, do not develop it. Even when leaves have developed the green colour, they lose it if deprived of light. Light is, therefore, the cause of the green colour of plants.

1928

1. Distinguish between Induction and Deduction, and show that the two processes supplement each other in scientific investigation.

2. "Water will always quench thirst." "Fire will always burn." What are the ultimate grounds of our assurance that universal propositions like these are true?

3. What is Hypothesis, and what is its value in Induction? Give an account of different kinds of hypotheses, with examples.

4. Point out the main differences between the popular and the scientific conceptions of a cause. How does the cause differ from *conditions*?

5. What is a Law? Distinguish clearly between the following kinds of Laws and add examples:—

Laws of the State, Laws of Thought, Empirical Laws, Laws of Nature.

6. Criticize Mill's "Experimental Methods," pointing out their value in scientific Induction, and bringing out their defects.

7. How would you prove or disprove that the growth of modern industrial organization and education in India has led to an increase of poverty?

8. Write explanatory notes on any *three* of the following:—

(1) Imperfect Induction.

(2) Plurality of Causes.

(3) The Method of Residues.

(4) The Inductive Syllogism.

9. Analyse fully any *three* of the following arguments and discuss their validity, pointing out and explaining fallacies, if any:—

(*a*) In a certain college, students were given intelligence tests. The results showed that Science classes were on the whole more intelligent than Arts classes. It is clear, therefore, that Science tends to develop the intelligence of a student.

(*b*) In Russia the Revolution was brought about by the Bolshevists; in China also the Bolshevists had something to do with the revolution; in India Bolshevist agents are said to be encouraging the revolutionary party. The natural conclusion seems to be that the French Revolution, and the Revolution in Turkey must have been engineered by Bolshevists.

(*c*) Talking of London, Smollett says, "The capital is become an overgrown monster; which like a dropsical head, will in time leave the body and extremities without nourishment and support . . . . what wonder that our villages are depopulated, and our farms are in want of day-labourers!"

(*d*) Gopal is having high fever. In the morning, his temperature was 99°; at 10 a.m., 101°; and now, at 2 p.m., 104°. In the evening, it must rise to 110° or 112°.

(*e*) During the Great War, trade was very brisk and all businessmen made large profits. Since the end of the War, there has been depression in trade and businessmen have suffered heavy losses. It is clear that peace is unfavourable to commercial prosperity.

1929

1. Have the inductive and deductive processes of reasoning anything in common? What is common to them? In what do they differ?

2. Explain the Law of Universal Causation and the Law of the Uniformity of Nature. Are these laws themselves the results of Induction? If not, how is each of them related to Induction?

3. What is an Experiment? How does it differ from simple Observation? Enumerate and illustrate the advantages that experiment possesses over observation.

4. Distinguish Natural from Artificial Classification. What makes the former more useful in science than the latter?

5. What do you understand by Plurality of Causes? Give an example, and show that the apparent plurality is the result of incomplete analysis either of the causes or of the effect.

6. Clearly distinguish the method of Simple Enumeration from that of Agreement, and explain why inferences based on the former are more precarious than those based on the latter.

7. How does Scientific Explanation differ from Popular? Describe and illustrate the different ways in which a phenomenon may be scientifically explained.

8. What conclusions would you draw from the following facts and figures? Indicate the processes of

reasoning involved and the methods employed in arriving at the inferences :—

In 1925 the number of women employed in factories in India was 247,514 as compared with 235,332 during the previous year. The entire factory population increased from 1,455,592 in 1924 to 1,494,958 in 1925, while the number of children employed in factories fell from 72,531 in 1924 to 68,725 in 1925. During the year the restrictions imposed on employment of children by the Factories Act of 1922, were made much more effective than before.

9. Analyse any *three* of the following arguments, and estimate their logical value, pointing out the fallacies they may contain. Give reasons for your criticism :—

(*a*) In the last two Intermediate examinations the percentage of passes in History has been considerably lower than that in other subjects. The teachers of History in the colleges must, therefore, be incompetent.

(*b*) Riches are a power like that of electricity. To get work out of electricity, it must be allowed to flow from a place of high to a place of low potential. Similarly the force of the guinea you have in your pocket depends wholly on the default of a guinea in your neighbour's pocket.

(*c*) A certain tourist who travelled up and down this country for a few months observed many under-fed, diseased, and uncared-for cows in the streets and in 'goushálás' and 'pinjrápoles.' She subsequently proclaimed to the world that she had seen with her own eyes how unkind the people of India were to the cow whom they professed to adore.

(*d*) There are general indications that the lot of the Indian agriculturist is now better than it was in the past. The multiplication of third-class passengers on the railways during the last decade, the increase of bullock carts and other wheeled traffic in most Indian districts, as also the increased absorption of rupees, which has taken place of late years, all go to show that more money is now available after the bare necessaries of life have been procured than there was previously.

(*e*) *Teacher:* How do heat and cold affect bodies?

Pupil: Heat expands bodies and cold contracts them.

Pupil: The days are longer in summer and

Teacher: Very good: how do we know this?

shorter in winter.

Teacher: Any other illustration?

Pupil: The river is quite full in summer and becomes a tiny stream in winter.

END